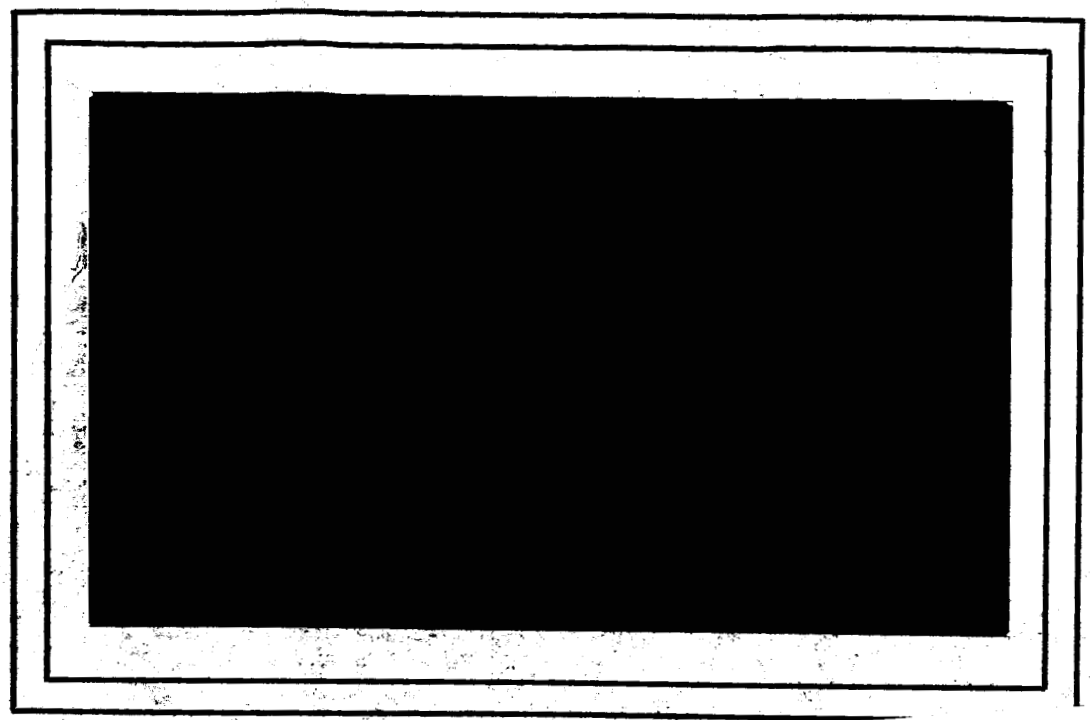

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Pattern Recognition: I. A Computer Program for Generating Synthetic Patterns

by

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The research project on Pattern Recognition is being conducted by Dr. Nancy S. Anderson, Associate Professor of Psychology and Research Consultant of the Computer Science Center together with Dr. Azriel Rosenfeld, Research Associate Professor (P.T.) at the Computer Science Center. The computer program described in this report was written by Mr. Norman F. Simenson, Research Programmer of the Computer Science Center. This project was supported primarily by the National Aeronautics and Space Administration under grant NsG 398, including total support for computing time and partial support for personnel.

ABSTRACT

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This report is designed to serve as a user's description and guide to a general program for generating patterns of overstruck alphanumeric characters. The program philosophy and data preparation sections are intended to enable a user to prepare data for the generation of patterns appropriate to his particular needs.

Appendix 1 contains a sample set of patterns generated by this program. Appendix 2 is a brief description of the main program and subroutines intended for use by programmers for modification and/or extension.

The program is written in FORTRAN II for use under IBSYS; it has been extensively tested on the 7090. author

CONTENTS

Introduction and Research Program

The processes of pictorial data analysis and pattern recognition by computers present many challenging problems to the scientist and engineer. The human observer's ability to perceive and 'recognize' patterns and pictures in "real time" appears to depend upon certain special purpose information processing mechanisms which are far from being understood.

The distinguishing characteristics of a pattern may be found in a specific portion rather than the pattern as a whole. A "pattern" in a picture can be discriminated from the rest of the picture by properties of luminance distribution, higher order statistical distributions of the occurrence of white, black, or gray portions, etc. To measure recognition data from pictures, figures must first be extracted from the picture. In many pattern recognition situations, there is a high degree of figure standardization in terms of luminance (black or white), orientation, and size. However, in many photo interpretation situations there may be little standardization, and patterns are perceived as a result of the human observer's ability to perform highly complex data analyses.

A number of recent automatic photo/interpretation studies such as described by Holmes, et al (1962) have devoted considerable effort to the figure extraction problem. Attneave (1954) and others have shown that the important information elements for human recognition of certain classes of patterns are to be found at the contours of patterns. Julesz (1962) has demonstrated how aspects of contour recognition can be investigated by the generation of black and white patterns with known statistical characteristics. Many of these investigators have indicated that certain measures of the redundancy of areas within a picture (or measures obtained from cross-correlation techniques between a mask shaped like the figure and the picture, Holmes, et. al. (1962))do result in the identification of contours or figures within a picture.

The present investigations are designed to correlate physical parameters with measures of human discrimination of coutours within patterns. The class of patterns used are similar to those described by Julesz (1962), in which a

computer program generates a matrix of cells which are black or white. The parameters chosen for the initial experiments are those of the higher order probability distributions of black or white cells in a matrix. Julesz (1962) has shown that changes in higher order probability distributions can introduce an identifiable change in contour. In studies of human pattern recognition, Anderson and Leonard (1958) have shown that qualitatively different kinds of dependencies in a pattern may hinder human recognition rather than enhance it.

The computer program described here was designed to generate classes of patterns to be used in human recognition tests. Experimental investigations will determine what characteristics of higher order dependencies among black and/or white cells in a matrix result in discrimination of contour and/or texture changes within a pattern.

The computer program entitled MATTY was originated and revised at the Computer Science Center in order to more efficiently generate the classes of patterns desired for the planned experimental program. The first parameters to be investigated are those of changes in the probability distributions of run lengths (of black or white cells) while holding the zero order probability of any cell being black or white constant at $\frac{1}{2}$.

PROGRAM PHILOSOPHY, MATTY VERSION III

The program was designed to be as versatile as possible. That is, the program is capable of generating series of patterns for different research approaches to the problem of pattern discrimination using synthetically generated patterns. It is hoped that one or more of these researches will yield a useable unidimensional measure of the discriminability of certain classes of patterns by human and/or infrahuman subjects.

The basic program produces two patterns of alphanumeric characters. The two patterns are printed out simultaneously as the left and right portions of a continuous field (i.e., the right margin of the left pattern is at the left margin of the right pattern). Each character position of each pattern may contain from 0 to 8 characters printed one upon the other (overstruck). The presence of a set of overstruck characters or a blank at any position of the pattern (MATT) is determined as a function of the probability distribution or other control provided by the user, and/or an internal random number generator.

The parameters controlled by the main program are the "run lengths" of the overstruck characters or the blanks on a single line. The run length is defined as the number of adjacent positions of overstruck characters (the 'Black' run length), or the number of adjacent positions of blanks, (the 'White' run length). The Black run lengths alternate with the White run lengths, the final run lengths being truncated at the margins. Each line (row) is independently generated, and the probability of any line beginning either with a Black run or a White run is 1/2. The probability governing the lengths of both the Black and White runs is independently controllable by the user for both the right and left patterns. The probability of any run length may be varied in increments of 1/4 or 1/3, and the run lengths themselves may vary from 1-4 adjacent positions.

The right portion (Right Bank) of the pattern may be generated independently of the left portion (Left Bank) of the pattern, or it may be generated as a function of the Left Bank pattern. The latter capability is provided through a subroutine access or 'gate' to the main program which provides for up to 56 special routines. (In fact,

only a 'Right' bank pattern need be generated.) The size and/or position of each pattern may be varied within the overall MATT size limit of 80 lines by 120 columns. Since the actual number of overstrike characters appearing at each MATT coordinate is individually controllable, program capacity exists for generating patterns of shades of grey independently of, or in conjunction with, the run length control.

A sample set of 21 patterns is included in Appendix 1. The right half of the matrix of these patterns differs from the left half by changes in the probability distributions of black and white runs of 1, 2, 3, and 4 cells. The Mean run length ($\bar{X}$) is the statistical average of both black and white runs.

Data Preparation

The data for this program are divided into logically and functionally independent units called Jobs. Each Job generates a series of MATTS (rectangular patterns of over-struck alphanumeric characters) which are a function of the Job data. The total of all the Jobs submitted for computation at any one time is called a Pass. In theory, any number of Jobs may be submitted at any one time (i.e., the Pass length is unlimited). However, MATTY is not set up to handle more than seven tapes (including the system tape) conveniently. (A feature incorporated to handle unlimited Passes is described under N CTRL Card B37(4).) The user should keep a record of how much tape is to be used on each unit. Otherwise, a tape may be filled to its End of Tape Mark, at which point FORTRAN II under IBSYS will cause the program to pause and indicate to the operator that another tape reel is required. However, this is not the recommended procedure to follow for Passes requiring more than one tape. (For further information about tape handling, see the remarks under the appropriate N CTRL card code sections below.)

The Jobs are stacked one behind the other after the * DATA System card. The order of the Jobs determines the order in which the output is generated. The Job numbers are internally assigned by MATTY. Each Pass should end with a DATA END card, prepared as described later. If only system tapes are being used, the DATA END card is normally optional (unless SENSE SWITCH 5 is in use at the user's location). If off-system tapes are being used, the Pass must end with the DATA END card, or the program will not pause to permit the operator to dismount tapes.

Each Job is composed of from two to four logically independent kinds of data. These are: N CTRL Card (one card), P DATA card(s) (one to twenty-six cards), FOGVEC card, and RANDNO card (one card). The inclusion of FOGVEC and RANDNO cards after the first Job is at the user's option but, if included, the proper code must be entered on the N CTRL card; otherwise, they are ignored and a spurious Abrupt Program Termination (APT) error output is generated. (In this case, the APT does not normally interrupt the logical flow of the program, but simply slows it down.) A FOGVEC and a RANDNO card must be included with the first Job, or the first Job and all of the following Jobs to the next Job with a FOGVEC and a RANDNO card are abruptly terminated. If any FOGVEC or RANDNO card is defective, all following Jobs to the next Job

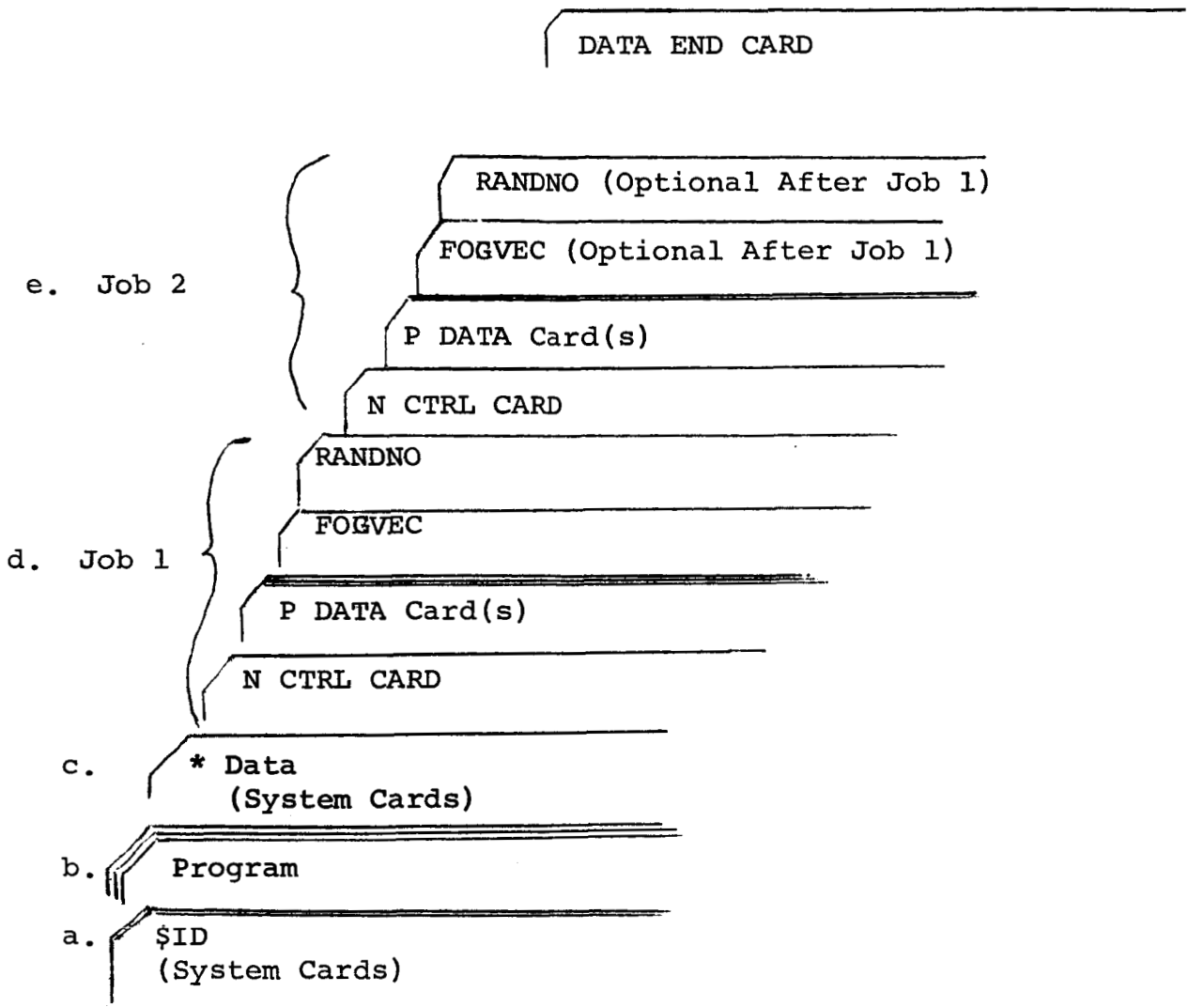

FIGURE 1. ORDER OF CARDS IN A PASS

with a valid FOGVEC or RANDNO card are abruptly terminated. Since all data cards (with the exception of the DATA END card) are identified by the code name entered in card columns 67-72, this code name must appear on all data cards exactly as described. The order of the data cards in the Job is critical; if the cards are out of order (except as noted below for the P DATA cards), an APT results, and the program procedes to the next Job (unless the N CTRL card is coded for a Kickout If Error In Job, in which case the Pass is terminated at that point).

The order of Cards in a Pass (See Figure 1)

a. System Cards
b. Program
c. System Cards (* DATA)
d. Job 1 — N CTRL Card
P DATA Card(s)
FOGVEC Card
RANDNO Card
e. Job 2 — N CTRL Card
P DATA Card(s)
FOGVEC Card (Optional after Job 1)
RANDNO Card (Optional after Job 1)
f. same as e
.
.
.
g. Data End Card

A. N CTRL Card (Table 1 lists all codes.)

The N CTRL card identifies the beginning of each Job, and may not be omitted even if it contains no N CTRL data (i.e., is blank except for card columns 67-72). In the event of an APT, the program searches for the next N CTRL card in order to read in the next Job. If an N CTRL card causes the APT (for example, if it is at the P DATA station of the preceding Job, it is nevertheless recognizes as the beginning of the next Job. The N CTRL card must be very carefully prepared, as virtually every position on the card is used to control some portion of the program, and each different number produces a different effect. In some cases, the same field is used for different kinds of data depending upon control code entries in other portions of the card. If the N CTRL card contains no data in columns 1-66, a basic

set of patterns of maximum dimensions is produced. Figure 2 shows a typical Final Output printing of the data.

BOOLEAN CODES. Many of the N CTRL Card columns shown in Table 1 are preceded by a B. This means that the decimal number punched in that column is considered as a Boolean command and is interpreted according to binary logic. This enables many more control functions to appear on one card and simplifies the internal program control. The Boolean commands operate as follows: a 1 punch is interpreted as command 1 only, a 2 punch as command 2 only, a 4 punch as command 4 only, and an 8 punch as command 8 only. A 3 punch is interpreted as commands 1 and 2, a 5 punch as commands 1 and 4, a 9 punch as commands 1 and 8, a 6 punch as commands 2 and 4, and a 7 punch is interpreted as commands 1, 2, and 4. Thus, for example, if a 7 punch appears in N CTRL card column 30, the Matt Head and Matt Printout are both suppressed, and the program checks for Looping In The Random Number Generator. (A typical Matt Head is shown in Figure 3.) Also, it is not possible to Suppress The Final Output if either (or both) a New Fogvec or a New Randno are commanded to be read in by a 2, 4, 6, or 7 in N CTRL card column 34. (A 7 punch will also Suppress the Initial Output.)

It should be noted that only those N CTRL card columns preceded by B are interpreted as containing Boolean commands. Thus, a 3 in N CTRL card column 1 is interpreted simply as a 3. Note also that no more than <u>one</u> number may be punched in any one of N CTRL card columns 1-66. If a Boolean 1, 2, and 4 are to be entered in a single column, only the single number 7 should be punched in that column. A multiple punch in N CTRL columns 1-66 causes an EXEM Kickout.

N CTRL CARD CODES. For an explanation of the use of N CTRL card columns 1 through 26, see N CTRL Codes B27(2), B27(4), B38(2), B38(4), and B31(1).

B27(1). Reverse Black and White Runs, Left Bank. If column 27 does not contain Boolean 1, index LX controls the distributions for the Left Bank Black Runs and LY controls the distributions for the Left Bank White Runs. (This Run refers to the run of black or white blocks which varies from 1 to 4.) For each P DATA card, all possible combinations (of the probability distributions appearing on a single P DATA card) of Black and White Runs are generated by stepping index LY down one for each Matt generated, and stepping index LX down one and resetting index LY each time index LY goes

Table 1. N CTRL CARD CODES FOR MATTY III

CARD COL		FUNCTION	N CTRL NO.
		Columns 1 Through 26 Are For N CTRL Starting Distributions	LL 1-26
		Left Bank = 1 - 13 Right Bank = 14 - 26 (0=Use Computed Max, 1-5 Will Readin, 7=0)	
		If SUBROUTINE SYMTRY Is Called, The Symtry Routines Desired Are Read As Boolean Commands From Columns 14 Through 26.	
B27	(1)	Reverse Black And White Runs, Left Bank	27
B27	(2)	N CTRL Takeover, LB Black Run Starting Distribution	27
B27	(4)	N CTRL Takeover, LB White Run Starting Distribution	27
B27	(8)		27
B28	(1)	RB Will Run	28
B28	(2)	Generate LB From Left To Right	28
B28	(4)	Generate RB From Right To Left	28
B28	(8)		28
29			29
B30	(1)	Suppress MATT Head	30
B30	(2)	Suppress MATT (Printout Only)	30
B30	(4)	Check For Looping In Random Number Generator	30
B30	(8)	Suppress MATT (MATT Generation And Printout)	30
B31	(1)	Call SYMTRY (No RB P DATA)	31
B31	(2)	Suppress Probability Limit Check	31
B31	(4)	Suppress RB Probability Check	31
B31	(8)	Suppress All Probability Check	31
B32	(1)	MATT Height Control	32
B32	(2)	Kickout If MATT Count Overflows	32
B32	(4)	Kickout If Error In Job	32
B32	(8)		32
33	-6-	MATT Width Control	33
33	-7-	MATT Width Control, Right Margin + 100	33
33	-8-	MATT Width Control, Right Margin And Intermargin + 100	33
33	-9-	MATT Width Control, All Margins + 100	33
B34	(1)	Suppress Initial Output	34
B34	(2)	Use New RANDNO	34
B34	(4)	Use New FOGVEC	34
B34	(8)	Suppress Final Output	34
35		NTAPOU = Print Output Tape Number (0=6)	35
36		KTAPOU = Punch Output Tape Number (0=7)	36

Table 1. Continued

CARD COL			N CTRL NO.
B37	(1)	Permit Unequal FOGVEC Words	37
B37	(2)	Save MATT Count, Add NC(52), And Continue	37
B37	(4)	Mount Additional Tape Section (Print Output)	37
B37	(8)		37
B38	(1)	Reverse Black And White Runs, Right Bank	38
B38	(2)	N CTRL Takeover, RB Black Run Starting Distribtution	38
B38	(4)	N CTRL Takeover, RB White Run Starting Distribution	38
B38	(8)		38
39			39
40			40
41		Number Of Endfiles At Job End Of Off-System Printed Output	41
42-43		Right MATT Margin	42
44-45		Left MATT Margin	43
46-47		MATT Intermargin	44
48-49		MATT First Print Line	45
50-51		MATT Final Print Line	46
52-53			47
54-55			48
56-57			49
58-59			50
60-62		MATT Limit (0=4)	51
63-66		MATT Count Begin After No. =	52
67-72		ID Name	

LEGEND

-6-	Decimal Number
(2)	Boolean Number
LB	Left Bank
RB	Right Bank

FINAL CUTPUT JCB NUMBER 1 FINAL CUTPUT JCB NUMBER 1 FINAL OUTPUT JCB NUMBER 1

(1) LEFT BANK PRCBABILITY NUMBERS AND MEAN NUMBERS
(P = PN/4, M = MN/4, PROBABILITY NUMBERS CUMULATE TO THE RIGHT)

(4) DISTRIBUTION- 1	DISTRIBUTION- 2	DISTRIBUTION- 3	DISTRIBUTION- 4	DISTRIBUTION- 5	(2) MEAN	(3) LL
4 4 4 4	C C C 4	-0 -C -C -C	-C -0 -0 -0	-0 -0 -0 -0	70	1

RIGHT BANK PRCBABILITY NUMBERS AND MEAN NUMBERS
(P = PN/4, M = MN/4, PROBABILITY NUMBERS CUMULATE TC THE RIGHT)

DISTRIBUTION- 1	DISTRIBUTION- 2	DISTRIBUTION- 3	DISTRIBUTION- 4	DISTRIBUTION- 5	MEAN	LL
4 4 4 4	C C 0 4	-0 -C -C -C	-C -0 -0 -0	-0 -0 -0 -C	70	14

(5) THE CVERSTRIKE CHARACTERS FOR THIS RUN ARE N A Z I • V X S A

(6) THE CONTROL CARD IS PUNCHED FOR CONTROL AS FOLLOWS

NC NC.	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
	5	6	-0	-C	8	1	7	-C	-C	-C	1	5	-0	-C	-0	12C	4	62	20	30	-0	-0	-0	-0	4	9999

(7)

LL VEC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	2	C	C	C	C	C	C	C	C	C	C	C	C	2	0	C	C	0	0	0	0	0	0	0	0	0

(8)

N CTRL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	1	-C	-C	-C	-C	-0	-C	-C	-C	-C	-C	-C	-0	1	-0	-C	-C	-0	-0	-0	-C	-0	-0	-0	-0	-0

(9) THE STARTING RANDOM NUMBER WAS OCTAL 524310726411 CONTROL NUMBER -0
THE TERMINAL RANDOM NUMBER WAS OCTAL 511143253711 CONTROL NUMBER 1
THE TOTAL NUMBER OF XIRAN CALLS WAS 1200. XIRAN LOOPED AT 0.
THEORETICAL E(X) MINUS OBSERVED E(X) OF IRA = 0.750E-02 FINAL MATT COUNT = 2

(10) THE INITIAL MATT NUMBER IS 10000 THE FINAL MATT NUMBER IS 10001

FIGURE 2, TYPICAL FINAL OUTPUT PAGE

LEGEND FOR FINAL OUTPUT DATA, FIGURE 2

1. Printout of Left Bank P DATA card distributions as they appear on the card: P = probability; PN = probability number; M = mean; MN = mean number.
2. The MEAN is actually the Mean number (Mean run length times 4) contained in P DATA card columns 21-22.
3. The entry positions of the P DATA cards in the LL Vector (entered in the order they are read in, except that the P DATA cards for the Right Bank begin at LL Vector position 14).
4. These entries are taken from P DATA card columns 1-4 for Distribution-1, 5-8 for Distribution-2, etc. Each is a set of probability numbers used to control the generation of 1 or more patterns for the Left or Right Bank.
5. The first group of letters represents the Left Bank Overstrike Word (the contents of FOGVEC card columns 41-48); the second group represents the Right Bank Overstrike Word (the contents of FOGVEC card columns 49-56).
6. The contents of NC Vector positions 27-52. Note: these numbers do not represent N CTRL card columns, but are the Vector numbers appearing in the right hand column of TABLE 1.
7. The contents of LL Vector positions 1-26, which are listed only if an N CTRL takeover is indicated or SUBROUTINE SYMTRY is called. The first 13 positions show the number of distributions punched into the Left Bank P DATA cards entered at the corresponding IBNK location; the second 13 positions (14-26) show the number of distributions punched into the Right Bank P DATA cards.
8. The contents of N CTRL Card columns 1-26, which are listed only if an N CTRL takeover is indicated, or SUBROUTINE SYMTRY is called. These numbers are used as the starting distribution numbers (a 7 punch is interpreted as a 0; a 0 punch, or a blank forces the corresponding value from the LL Vector to be used).
9. The data pertaining to the random number generator, which are listed only if the random number generator has been used in the Job. The theoretical E(X) of IRA, the random numbers (which vary between 0 and 3), is 1.5. The difference between the Theoretical E(X) and Observed E(X) is shown and is an indication of the average error of the random number generator. A number greater than 0 for the optional XIRAN Loop check indicates the length of the loop generated, if it is less than or equal to the number of XIRAN calls.
10. The first and last Matt numbers are always listed, but may run to 999,999, whereas the actual Matt Head numbers are listed modulo 10,000.

TYPICAL MATT HEAD

10-1	1 2 3 4	-2 0 2 4 4		
10-2	2 2 2 4	-3 0 3 3 4	0001	542310726411

SYMBOLIC CODING FOR THE ABOVE MATT HEAD

A-LX	DPN	-LY	DPN		
B-NX	DPN	-NY	DPN	MTN	ORA

EXPLANATION OF MATT CODE HEAD

A = The Mean number entered on the Left Bank P DATA card from which the distributions used to generate the Left Bank pattern were taken

B = Same as A for the Right Bank

LX = The setting of index LX which determines the probability distribution taken from the Left Bank P DATA card to generate the Left Bank Black run lengths (unless Black and White Runs are reversed).

LY = The same as LX, but normally controls White run length (unless Black and White Runs are reversed).

NX = The same as LX for the Right Bank.

NY = The same as LY for the Right Bank.

DPN = The probability numbers listed in the indexed Distribution field of the P DATA card whose Mean number appears at A (or B).

MTN = Matt Number

ORA = The random number (in octal) used to begin a series. Appears on the first Matt after a Right Bank change, unless SUBROUTINE SYMTRY is called, in which case it appears on the first MATT after a Left Bank change.

FIGURE 3. MATT HEAD AND CODED EXPLANATION

to 0. Index LX and LY are both normally initially set to the number of the rightmost distribution appearing on the appropriate Left Bank P DATA card. (However, these initial settings may be altered by N CTRL commands B27(2) and B27(4).) If a Boolean one (decimal 1,3,5,7, or 9) appears in N CTRL card column 27, index LX is given control of the distributions for the Left Bank White Runs and index LY is given control of the distributions for the Left Bank Black Runs. Since the stepping of the indexes remains the same, the order of change of the Black and White Run Lengths is reversed.

If two Jobs are exactly identical (including the FOGVEC Left Bank word and RANDNO number) except that one contains a Boolean 1 in N CTRL card column 27 and the other does not, then the Left Banks of the two Jobs will be exact 'negatives' of each other, i.e., each White Run Length on the one will appear as a Black Run Length in the corresponding location on the other, and vice versa.

B27(2). N CTRL Takeover, LB Black Run Starting Distribution. It is possible to restrict the number of combinations of Left Bank Black and White Run lengths generated for a given P DATA card in the following way. If a Boolean 2 (decimal 2,3,6 or 7) appears in N CTRL card column 27, the maximum initial setting of index LX is taken from the appropriate N CTRL card column 1-13, which corresponds to the order of the Left Bank P DATA cards (i.e., the LX setting for the third P DATA card must appear in N CTRL card column three). Thus, if there are 5 distributions on Left Bank P DATA card 7, but it is desired that the distributions for the Black Runs (assuming no Boolean 1 in N CTRL card column 27) be restricted to the leftmost 3 only, then a 3 should be punched in N CTRL card column 7, and a 2 or a 6 in column 27. In such a case only 15 patterns would be generated (instead of the normal 25). If it is desired to restrict the distributions to a rightmost set, then the MATT Limit should be used to terminate the Job after the correct number of Matts have been generated. Suppose, in the previous example, it was desired to restrict the distributions for the Black Runs to the P DATA card distributions 2 through 4 inclusive. Then the N CTRL card should have a 4 in column 7, a 2 or a 6 in column 27, and a 15 in columns 61 and 62. However, if the MATT Limit is used, the size of the Job is accordingly restricted, since the entire Job is terminated when the MATT Count goes to 15, and no other P DATA card is used (except for the initial Right Bank generation).

If the N CTRL card column corresponding to a P DATA card is blank or contains a zero (and a Boolean 2 is in N CTRL card column 27), LX is set to the number of the rightmost distribution on the P DATA card (i.e., the Boolean 2 in column 27 has no effect on that P DATA card). If a 7 appears in one or more of columns 1-13, the corresponding P DATA card is bypassed. If any column 1-13 contains a number greater than the number of distributions on the corresponding P DATA card, an Error Condition results. If no Boolean 2 appears in N CTRL card column 27, the data in columns 1-13 have no effect upon index LX.

B27(4). N CTRL Takeover, LB White Run Starting Distribution. If a Boolean 4 (decimal 4,5,6, or 7) appears in N CTRL card column 27, the maximum initial setting of index LY is taken from the appropriate N CTRL card column 1-13. For any columns 1-13 which are blank or contain zeros, the maximum initial setting of LY is the number of the rightmost distribution on the corresponding P DATA card. If any columns 1-13 contain 7's, the corresponding P DATA cards are bypassed. If any column 1-13 contains a number greater than the number of distributions on the corresponding P DATA card, an Error Condition will result. If no Boolean 4 appears in N CTRL card column 27, the data in columns 1-13 have no effect upon index LY.

B28(1). RB Will Run. If column 28 does not contain a Boolean 1, the first pattern generated is a Right Bank pattern from distributions on the last Right Bank P DATA card. Then, all possible Left Bank patterns are generated and printed out with the original Right Bank pattern before control is returned to the Right Bank. However, the Job is terminated at that point unless a Boolean 1 appears in N CTRL card column 28.

If a Boolean 1 appears in column 28, the Right Bank Run Length distributions change in a manner analogous to those for the Left Bank, except that for each Right Bank pattern generated, all possible Left Bank patterns are generated. Thus, the requirement of a Boolean 1 in column 28 is a safeguard against excessive output.

B28(2). Generate LB from Left to Right. If Column 28 does not contain a Boolean 2, each line is independently generated from the Intermargin to the outer margins. Each line begins with a Black or a White Run (the probability of either being one-half); thereafter, the Black and White Runs alternate, the last run being truncated at an outer margin.

If a Boolean 2 appears in N CTRL card column 28, the lines for the Left Bank are generated in the reverse direction, from the left Margin to the Intermargin, and are truncated at the Intermargin.

B28(4). Generate RB From Right to Left. If a Boolean 4 appears in N CTRL card column 28, the lines for the Right Bank are generated in the reverse direction, from the Right Margin to the Intermargin, and are truncated at the Intermargin.

B30(1). Suppress MATT Head. If a Boolean 1 appears in N CTRL card column 30, the entire MATT Heading (except for the MATT number, if the MATT is not also suppressed) is suppressed.

B30(2). Suppress MATT (Printout Only). If a Boolean 2 appears in N CTRL card column 30, the MATTS are not printed out, but continue to be generated. This command is useful for generating the MATT Heads separately from the MATTS, and accurately representing the random numbers appearing in the Heading accompanying each Right Bank change (or Left Bank change, if SUBROUTINE SYMTRY is called). Note that in this condition a page skip occurs between Headings just prior to each change of Right Bank pattern, otherwise they are suppressed. If both the MATT Heading and the MATT Printout are suppressed, only the Initial Output and the Final Output (if these are not also suppressed) appear. There will be no blank pages between them.

B30(4). Check For Looping In Random Number Generators. If a Boolean 4 appears in N CTRL card column 30, a simple check is made to see if looping (i.e., repetition of a particular sequence of numbers) has occurred within the sequence of random numbers generated for a Job. If looping has occurred, the length of the loop (i.e., the number of 'random' numbers generated before one is repeated) is printed out in the Final Output.

B30(8). Suppress Matt (Matt Generation and Printout). A Boolean 8 (a decimal 8 or 9) in N CTRL card column 30 suppresses both the Generation and Printout of the MATT. This command results in a slightly faster program execution than a Boolean 2 in column 30, but the random numbers printed out in the MATT Heads (if these are not also suppressed) are merely repetitions of the starting random number for the Job. (Note, however, that the Matt Count still sequences correctly.)

B31(1) Call Symtry (No RB P DATA). For a full description of the function of SUBROUTINE SYMTRY, see the appropriately entitled sub-section under Program Description, Subroutines. A Boolean 1 in N CTRL card column 31 causes SUBROUTINE SYMTRY to be called and produces certain major modifications in the operation of the Main Program. Principal among these is that the P DATA for the Right Bank is neither read in nor printed out. Consequently, if SUBROUTINE SYMTRY is called, the Right Bank P DATA must be omitted, or an APT will result. N CTRL card columns 14-26 (normally used for N CTRL Takeover, RB Black and/or White Starting Distribution numbers) are used to call in the specific Symtry Routines and are interpreted as Boolean commands (i.e., a 7 in column 26 will call in Symtry Routines 1,2,and 4). All Symtry Routines called for are executed with each change of Left Bank pattern. For a listing of the function of each Symtry Routine, see the section of this report so entitled. If any Symtry Routine is called for which is not available, an Error Routine is initiated. If no Symtry Routine is called for (i.e., card columns 14-26 are all blank or contain zeros) and SUBROUTINE SYMTRY is called (by a Boolean 1 in N CTRL card column 31), only Left Bank patterns are printed out.

B31(2). Suppress Probability Limit Check. If column 31 does not contain a Boolean 2 the program checks all P DATA distribution numbers to see that they cumulate to 4 (i.e., that for all non-zero distributions, the fourth distribution number is 4). However, if it is desired to use probability changes of 1/3 (instead of the normal 1/4), then the distributions should cumulate to 3, and a Boolean 2 in N CTRL card column 31 suppresses the check of the fourth distribution number.

B31(4). Suppress RB Probability Check. In addition to the Probability check noted above, P DATA distributions are also checked to see that they uniformly cumulate to the right and that they average to the Mean. All of these checks are omitted for the Right Bank if a Boolean 4 appears in N CTRL card column 31. (Note: it is not necessary to suppress the Right Bank Probability Checks if SUBROUTINE SYMTRY is called.)

B31(8). Suppress All Probability Check. A Boolean 8 in N CTRL card column 31 suppresses all of the Probability Checks noted above for all P DATA for the Right and Left Banks. However, it is still necessary that some number

greater than 0 be entered for the Mean on the P DATA cards (columns 21-22), as all P DATA cards with a zero mean are ignored.

B32(1). MATT Height Control. The basic MATT is 50 lines deep if the system tape is being used, and up to 80 lines (depending upon the value of JLL, which is set in SUBROUTINE LIMITS) if an off-system tape is being used. If smaller dimensions are desired, the First and Final Print Lines may be set to any line in the MATT within the normal limits. Print Lines may not be set less than 1 nor greater than the maximum noted above. The First Print Line may not exceed the Final Print Line. If a Boolean 1 appears in N CTRL card column 32, the setting for the First Print Line is taken from N CTRL card columns 48-49, and for the Final Print Line from columns 50-51 (which are read as fields, for example, a 1 in 48 and a blank in 49 is interpreted as First Print Line equals 10). Both values must appear; blanks are read as a zero and an Error Routine is initiated if either value exceeds the Matt Line Limits.

B32(2) Kickout If MATT Count Overflows. If a Boolean 2 appears in N CTRL card column 32, the Pass is terminated at the end of any Job in which the number of MATTS generated is equal to the value entered in N CTRL card columns 60-62, which are read as a single field. If columns 60-62 are all blank, zero, or negative, the Kickout occurs after any Job in which the number of MATTS generated is 4. MATT Heads count as MATTS if the MATT Printouts are suppressed.

B32(4) Kickout If Error in Job. If a Boolean 4 appears in N CTRL card column 32, the Pass is terminated after any Job in which an error has been detected.

33(6,7,8,9) MATT Width Control. The basic MATT is 120 columns wide. The Left Bank runs from columns 1 to 60 inclusive and the Right Bank from 61 to 120. The Intermargin is taken as the rightmost margin of the Left Bank. If a smaller Matt is desired, or if it is desired to vary the position of the Intermargin, the appropriate entry should appear in N CTRL card column 33. If a 6,7,8, or 9 appears in Column 33, the setting for the Right Margin is taken from N CTRL card columns 42-43, for the Left Margin from columns 44-45, and for the Intermargin from columns 46-47. If a 7 is used, 100 is added to the value taken from columns 42-43; if an 8 is used, 100 is added to the value taken from columns 42-43 and to the value taken from columns 46-47; if

a 9 is used, 100 is added to each of the values read in. (Thus, if it is desired that the Left Margin be at column 15, the Intermargin at 100, and the Right Margin at 120, then a 20 should appear in columns 42-43, a 15 in columns 44-45, blanks or zeros in columns 46-47, and an 8 in column 33.) All values must appear, blanks are read as zeros. An Error Routine is initiated if the MATT Margin Limits are exceeded, if the Intermargin is less than the Left Margin, or if it is greater than or equal to the Right Margin.

B34(1). Suppress Initial Output. If a Boolean 1 appears in N CTRL card column 34, the printing of the Initial Output is omitted.

B34(2). Use New RANDNO. If it is desired that some Job after the first begin with a particular random number, then a RANDNO card should be included with that Job and a Boolean 2 in N CTRL card column 34 will cause it to be read in. (If a Boolean 2 appears in column 34 and the RANDNO card is omitted, an APT results for that Job and for all following Jobs to the next one with a RANDNO card. If a RANDNO card is included with a Job and there is no Boolean 2 in column 34, a single spurious APT results which does not in any way interrupt the logical flow of the Pass.)

B34(4). Use New FOGVEC. If it is desired that some Job after the first begin with a new set of overstrike characters, then the new FOGVEC card should be included with that Job and a Boolean 4 in N CTRL Card column 34 will cause it to be read in. (If a Boolean 4 appears in column 34 and the FOGVEC card is omitted, an APT results for that Job and for all following Jobs to the next one with a FOGVEC card. If a FOGVEC card is included with a Job and there is no Boolean 4 in column 34, a spurious APT results which does not in any way interrupt the logical flow of the Pass unless a RANDNO card was also to have been read in on that Job. In such a case, since the APT caused by the FOGVEC card causes the readin of the RANDNO card to be bypassed, APTs result for all following Jobs to the next one with a RANDNO card.)

B34(8). Suppress Final Output. If a Boolean 8 appears in N CTRL card column 34, the printing of the Final Output is omitted. Note, the Error Diagnostic Report cannot be suppressed; if the random number generator is used, the information pertaining to it is printed; and if an off-system

tape is being used, the first and final MATT numbers are always noted on the system tape.

35. NTAPOU = Print Output Tape Number (0 = 6). The number in N CTRL card column 35 determines the logical number of the tape for printed output. These numbers may not exactly correspond to the logical tape numbers (for example, at this site, the number 1 is used to represent tape logical number 10). No system tape may be operated through the use of N CTRL card column 35. If it is desired that the printed output appear on the normal system tape for printed output, column 35 should be left blank or a zero may be punched in it. (This causes the output to be written on tape 6, which is the system tape for printed output at this site.)

The first time that any tape unit is called for on a Pass, the program automatically generates the appropriate on-line operator instructions for mounting and labeling the tape, causes the program to pause, and rewinds the tape upon restarting. Thereafter, each Job allocated to that tape is noted by an on-line printout, but no operator instructions are generated nor does the program pause (unless an End of Tape mark is sensed). If a DATA END card terminates the Pass, an on-line operator message is generated instructing the operator to save and label only the tapes listed at that point, which are those tapes which have output on them.

If off-system tapes have been used and have output on them, the program pauses at this juncture to permit the operator to dismount them. Otherwise, it prints out a message to save no tapes and does not pause. If an Error Routine is initiated for any Job, the Error Output and Final Output are written on the system tape, and the off-system tape is backspaced to its position at the start of the Job. Hence, if all of the Jobs allocated to an off-system tape contain errors, the tape is blank at the end of the Pass. (Note: if the printed output is already allocated for the system tape, no backspacing occurs.) A copy of the Final Output (unless suppressed), data pertaining to the random number generator (if used), and the first and last MATT numbers are always written on the system tape.

36. KTAPOU = Punch Output Tape Number (0 = 7). This column controls the tape numbers, on-line operator instructions, and program pauses for the punched output in a manner exactly analogous to that for the printed output.

The punched output consists of a single RANDNO card at the end of each Job bearing the final random number of that Job (the one which is used as the starting random number on the following Job, unless a new RANDNO card is read in), and a control number. (For an explanation see the section on the RANDNO card.) If a blank or a zero appears in N CTRL card column 36, the punched output is allocated to the system tape for punched output (tape 7 at this site).

B37(1) Permit Unequal FOGVEC Words. The check of the overstrike characters assigned to the Left and Right Bank incorporates a check to see that the same number of characters are assigned to each. This is to prevent the possibility of an error in the preparation of the FOGVEC card which would result in fewer characters being assigned to one Bank than the other. (For example, starting the FOGVEC Left Bank word in column 40 instead of 41, for example, and thus ending the Right Bank word in column 55.)

If, however, it is desired that the number of overstrike characters differ between the Banks, this check may be bypassed by a Boolean 1 in N CTRL card column 37.

B37(2) Save MATT Count, Add NC(52), and Continue. If Column 37 does not contain a Boolean 2 the MATT Count begins with first number following the number punched in N CTRL card columns 63-66(NC(52)). Thus, if the latter columns contain blanks or zeros, the first MATT number is 1. If a Boolean 2 appears in N CTRL card column 37, the MATT count remaining from the preceding Job is not reset, but the contents of N CTRL card columns 63-66 are added to it, and the first MATT number of the new Job is one greater than that sum. Thus, if it isdesired that the MATTS in a series of Jobs should be sequentially numbered, it is only necessary to put a Boolean 2 in N CTRL card column 37 for each Job after the first in the set and have columns 63-66 contain blanks or zeros, except for the first N CTRL card of the set, which should contain the desired starting number.

B37(4) Mount Additional Tape Section (Print Output). If at any time, it is desired to use more off-system tapes than the six tapes normally available for a single MATTY Pass, then the oversized Pass should be broken down into two or more smaller Passes. However, if for any reason more than six off-system tapes must be employed for printed output on a single Pass, a Boolean 4 in column 37 of the

N CTRL card for the first Job to be allocated to the second (or subsequent) tape reel on any tape unit generates the appropriate on-line operator instructions to mount a new reel and save the old one, causes a program pause to permit the operation to take place, and rewinds the new reel. (If N CTRL card column 35 is blank or contains a zero, the Boolean 4 in column 37 is ignored.)

Since a Boolean 4 in column 37 generates a change reels instruction, program pause, and tape rewind each time it is used, it should appear only on the N CTRL card of the first Job to be allocated to a second (or subsequent) reel for a tape unit previously used. It should never be used on the N CTRL card of any of the Jobs allocated to the first reel used on any tape unit.

B38(1) Reverse Black and White Runs, Right Bank. A Boolean 1 in N CTRL card column 38 produces an exactly analogous effect upon the Right Bank as a Boolean 1 in column 27 produces upon the Left Bank. However, the Right Bank index normally controlling Black Runs is NX and that normally controlling White Runs is NY. The NY index is stepped down one (if a Boolean 1 appears in N CTRL card column 28) for each generation of a complete set of Left Bank patterns. Index NX is stepped down one and index NY is reset each time index NY goes to 0. Index NX and NY are both normally initially set to the number of the rightmost distribution appearing on the appropriate Right Bank P DATA card. (However, these initial settings may be altered by N CTRL commands B38(2) and B38(4).)

B38(2) N CTRL Takeover, RB Black Run starting Distribution. A Boolean 2 in N CTRL card column 38 produces an exactly analogous effect upon the Right Bank as a Boolean 2 in column 27 produces upon the Left Bank. However, all Right Bank P DATA cards are numbered beginning with the number 14, regardless of the actual number of Left Bank P DATA cards. Hence, the maximum initial setting of index NX is taken from the appropriate N CTRL card column 14-26, which corresponds to the order of the Right Bank P DATA cards (i.e., the NX setting for the third Right Bank P DATA card must appear in N CTRL card column 16). If a Boolean 1 appears in N CTRL card column 31, a Boolean 2 in column 38 is ignored.

B38(4) N CTRL Takeover, RB White Run Starting Distribution. If a Boolean 4 appears in N CTRL card column 38,

the maximum initial setting of index NY is taken from the appropriate N CTRL card column 14-26. Otherwise a Boolean 4 in column 38 produces an exactly analogous effect upon the Right Bank as a Boolean 4 in column 27 produces on the Left Bank. If a Boolean 1 appears in column 31, a Boolean 4 in column 38 is ignored.

41. Number of Endfiles At Job End Of Off-System Printed Output. Any number of Endfile marks from 0 to 9 may be written at the end of the printed output of each Job allocated to an off-system tape by punching the desired number in N CTRL card column 41. A blank is read as a zero. This feature is not available for off-system tapes allotted for punched output. If a DATA END card appears at the end of the Block, three Endfile marks are automatically written on all off-system tapes allotted for punched output.

42. (N CTRL card columns 42-43) Right MATT Margin. See N CTRL commands for N CTRL No. 33.

43. (N CTRL card columns 44-45) Left MATT Margin. See N CTRL commands for N CTRL No. 33.

44. (N CTRL card columns 46-47) MATT Intermargin. See N CTRL commands for N CTRL No. 33.

45. (N CTRL card columns 48-49) MATT First Print Line. See N CTRL B32(1).

46. (N CTRL card columns 50-51) MATT Final Print Line. See N CTRL B32(1).

51. (N CTRL card columns 60-62) MATT Limit (0 = 4). The maximum number of MATTS which are to be printed out must be entered in N CTRL card columns 60-62. If these columns contain zeros or blanks the maximum number of MATTS printed out is 4. If the "Kickout If MATT Count Overflows" command is used (a Boolean 2 in N CTRL card column 32), the number entered in columns 60-62 should be at least 1 more than the number of MATTS expected, since a Kickout occurs whenever the MATT Count equals the number in these columns. The MATT Limit may also be used to limit the number of MATTS generated from any one set of P DATA card distributions (see N CTRL B27(2) for a fuller explanation). Blanks are interpreted as zeros.

52. (N CTRL card columns 63-66) MATT Count Begin After No. = . The number of the first MATT is normally equal to the contents of N CTRL card columns 63-66 plus 1. However, a Boolean 2 in N CTRL card column 37 causes the contents of columns 63-66 to be added to the existing MATT number, and the first MATT number is equal to this sum plus 1. Blanks are interpreted as zeros. The MATT number does not in any way effect the MATT Count.

THE N CTRL ID NAME must appear in N CTRL card columns 67-72 exactly as follows: an N, a blank, a C, a T, an R, and an L.

B. P DATA Card

The P DATA Card contains the probability distribution numbers for the generation of the MATTS. Separate sets of P DATA cards must be prepared for the Left Bank and Right Bank, since these data are read in separately. The first thirteen P DATA cards are read in as Left Bank data, and the last thirteen P DATA cards as Right Bank data, except as provided below.

If it is desired to use less than 13 P DATA cards for either or both Banks, two methods may be employed. P DATA cards which are blank except for the ID Name in columns 67-72 may be placed as spacers at any point. They read in and occupy a position in the internal data array, but are otherwise ignored (they are not even printed out). That is, if the first and third P DATA cards contain data and the second one is blank, only the first and third P DATA cards are used to generate MATTS, but for purposes of N CTRL Takeover, Left Bank, the settings for LX and for LY for the third P DATA card must appear in N CTRL card column 3. Consequently, it is possible to fill out a deck of P DATA cards with enough blank P DATA cards to make 13 for the Left Bank and 13 for the Right Bank.

An alternate, and somewhat speedier, method is available for reading in less than the full 26 P DATA cards. If a 77 appears in columns 65-66 on any of the first 13 P DATA cards, the card count is immediately stepped up and the next card is read in as the fourteenth (i.e., the first Right Bank) P DATA card. If a 99 appears in columns 65-66 when the P DATA cards are being read in as Right Bank data, the reading of P DATA cards is immediately terminated, and

the program procedes to the FOGVEC station. However, if a 99 appears in columns 65-66 when the P DATA cards are entering as Left Bank data, it is ignored; similarly, a 77 appearing in columns 65-66 when the P DATA cards are entering as Right Bank data is ignored.

If SUBROUTINE SYMTRY is called (by a Boolean 1 in N CTRL card column 31), no P DATA are read in for the Right Bank (i.e., the reading of P DATA cards terminates after the first thirteen cards are read in or after the first card with a 77 in columns 65-66 is read).

The first twenty columns of the P DATA card are divided into five fields, each field corresponding to a complete set of 4 probability distribution numbers. Distribution 1 is taken from P DATA card columns 1-4, Distribution 2 from 5-8, Distribution 3 from 9-12, Distribution 4 from 13-16, and Distribution 5 from 17-20. The Mean Number (MN) for the distributions is entered in columns 21-22. (MN is the Mean run length times 4, i.e., a Mean Number of 10 is a Mean run length of 2 1/2). Blanks are interpreted as zeros.

The probability numbers (PN) are the numerators of the fractional probabilities (assuming the denominator is a fixed 4 or 3, for example), cumulated to the right in each distribution. Thus, to find the actual probability number for any given run length within a distribution, it is necessary to subtract the left hand neighbor (unless a run length of 1 is being considered).

For example, translation of the numbers 1334 punched in a P DATA card columns 9-12 to fractional probabilities, is as follows. The first PN of a distribution is equal to the number in that column, in this case, 1. The next and subsequent PN's are equal to the number in the column minus its left hand neighbor. Hence PN(2) = 3-1 = 2; PN(3) = 3-3 = 0; PN(4) = 4-3 = 1. Dividing all of the PN's by 4 yields: ¼;, 2/4 = ½;, 0;, ¼. Hence, this probability distribution generates a run length of 1 with a probability of ¼, of 2 with a probability of ½, of 3 with a probability of 0, and of 4 with a probability of ¼. The Mean run length is equal to (¼ · 1) + (½ · 2) + (0 · 3) + (¼ · 4) = 2¼. The Mean Number equals 4 x 2¼ = 10 (which should appear in columns 21-22). Since the original distribution was in P DATA card columns 9-12, this is third distribution on that card.

For example, suppose we wish to convert the probabilities 0, ¼, ½, ¼ (for run lengths of 1,2,3, and 4 respectively) into cumulative PN's and to find their MN. First, multiply by 4, yielding 0,1,2,1. Then, multiply each number by its corresponding run length and sum the products to get the Mean number, i.e., MN = (0 • 1) + (1 • 2) + (2 • 3) + (1 • 4) = 13. To get the cumulative PN's, form the cumulative sums of each PN with its left hand neighbor, i.e., PN(1) = 0; PN(2) = 0 + 1 = 1; PN(3) = 1 + 2 = 3; PN(4) = 3 + 1 = 4.

Any distribution to the right of the zero distribution is ignored. All P DATA cards with zero mean's (i.e., columns 21-22 blank or containing zero's) are ignored, even if the Probability Check is suppressed by the appropriate N CTRL card code. The distributions for the Black and White Runs for either the Left Bank or Right Bank are always taken from the same P DATA card. Hence, if all of the distributions on the card average to the mean, the mean Black and White run lengths are always equal, yielding an average probability of ½ that any arbitrary square is either black or white.

The P DATA ID NAME must appear in P DATA card columns 67-72 exactly as follows: A P, a blank, a D, an A, a T, and an A.

C. FOGVEC Card

The FOGVEC Card immediately follows the P DATA card(s), if it is included in the Job. The FOGVEC card must be included in the first Job of a Pass and in every Job in which a Boolean 4 appears in N CTRL card column 34. The FOGVEC card must be omitted from every Job after the first which does not have a Boolean 4 in N CTRL card column 34.

Columns 41-48, inclusive, of the FOGVEC card contain the Left Bank overstrike characters (Left Bank word); columns 49-56, inclusive, contain the Right Bank overstrike characters (Right Bank word). The words must be packed to the left in their respective fields; a blank to the left of any character within a word initiates an Error Routine. Each word is checked separately. Normally, blanks to the right of each overstrike word (providing the word contains at least one overstrike character) are ignored; however, if a blank is detected within the word, all blank columns in the word are listed.

A check is also made to see that the overstrike words contain the same number of overstrike characters. This check may be bypassed (if it is desired that the words of unequal length) by putting a Boolean 1 in N CTRL card column 37.

For example, suppose it is desired that the word FOG be used for both the Left Bank and Right Bank. Then the word must be punched into the FOGVEC card twice as follows:

Card Column	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
	F	O	G						F	O	G					

These three character words initiate a three times overstrike of the letters F, O, and G in each Bank.

THE FOGVEC ID NAME must appear in FOGVEC card columns 67-72 exactly as follows: an F, an 0, a G, a V, an E, and a C.

D. RANDNO Card

The RANDNO Card immediately follows the FOGVEC card, if included, or after the P DATA card(s), if included in the Job. The RANDNO Card must be included in the first Job of a Pass and in every Job in which a Boolean 2 appears in N CTRL card column 34. The RANDNO card must be omitted from every Job after the first which does not have a Boolean 2 in N CTRL card column 34.

Columns 1-12, inclusive, of the RANDNO card contain the starting random number for the Job with which it appears. This number must be an odd number (i.e., the number in RANDNO card column 12 must be either a 1,3,5, or 7, but preferably a 1, since this yields the largest loop of random numbers), and it must be in OCTAL form (i.e., no entry in any one of columns 1-12 may exceed 7). If two identical Jobs are started with the same random number and FOGVEC words, the MATTS produced will be identical, since the same sequence of numbers are generated each time the same starting random number is used. (See also the description for the use of N CTRL codes B27(1) and B38(1).)

At the end of each Job, a new RANDNO card is generated by the program which contains the final random number generated in that Job (the first to be used in the following

Job, unless it contains its own RANDNO card).

For ease of identification, RANDNO card columns 65-66 are used for an ID number which may range from 0-99. If the first RANDNO card in a Pass contains a blank or zeros in columns 65-66, it is assigned the number 0 and all subsequent RANDNO cards generated by the program are assigned numbers in ascending order. If a number other than 0 appears in columns 65-66 the internally assigned numbers begin with the next number. (The numbering system is modulo 100, hence if the ID number of the first card in is 98, the internally generated RANDNO cards will bear the numbers 99, 00, 01,...). If subsequent RANDNO cards appear in the Pass with columns 65-66 blank or containing zeros, they are 'assigned' the next number following the one assigned to the RANDNO card generated at the end of the preceding Job, and the numbering continues from there (i.e., a gap of a single ID number appears in the generated RANDNO cards for each Job containing a RANDNO card with columns 65-66 blank or containing zeros). If a subsequent RANDNO card appears in the Pass containing an ID number, all subsequent RANDNO cards generated by the program are numbered sequentially from that number on. (For example, if Jobs 1, 4, and 7 contain RANDNO cards with ID numbers of 0, 0, and 1 respectively, the generated RANDNO cards will bear the numbers 1,2,3,5, 6,7, and 2.)

THE RANDNO ID NAME must appear in RANDNO card columns 67-72 **exactly as follows:** an R, an A, an N, a D, an N, and a 0.

E. **DATA END Card**

The DATA END Card must be prepared exactly as follows: a D must appear in column 67, an A in 68, a T in 69, an A in 70, an E in 71, an N in 72, and an optional D in 73.

F. SYMTRY ROUTINES. The functions of Symtry Routines presently incorporated into the program are listed below. There is ample capacity for up to 56 routines within MATTY, VERSION III, and only minor changes would be required to double that capacity. Therefore, it is expected that the number of Symtry Routines will quickly grow larger (for example, inclusion of the capacity to generate the two-dimentional symmetry point groups would use up most of the

present capacity). It is to be hoped that users will communicate with the authors regarding any Symtry Routines added.

It is to be noted, that if the SYM SUBROUTINE binary deck is properly collated with the rest of the deck, a given Symtry Routine call number may be used to generate any one of an unlimited number of functions, depending upon which SYM binary deck is included with the program deck on that Pass.

SYMTRY ROUTINE 1 (called by a Boolean 1 in N CTRL card column 26, i.e., a decimal 1,3,5, or 7) generates a basic pattern which is a mirror image of the Left Bank. That is, the Left Bank right border (at the Intermargin) appears as the Right Bank left border. If the Left Bank is wider than the Right Bank, the Right Bank pattern is truncated at the Right Margin, except as noted below. The direction of generation of the Right Bank may be reversed by the appropriate N CTRL command, in which case the left border of the Right Bank corresponds to the Left Margin of the Left Bank. The proper N CTRL command also causes a 'negative' image to be generated.

If the Left Bank is narrower than the Right Bank, after the Right Bank image of the Left Bank is generated, an exact duplicate of the Left Bank is generated to the right of the image; thereafter, the image pattern and Left Bank pattern alternate until the Right Margin is reached. If the Right Margin is at column 120 and the Left Margin is to the right of column 1, the pattern continues 'around' column 120 into column 1 and continues on until truncated at the left of the Left Margin.

SYMTRY ROUTINE 2 (called by a logical 2 in N CTRL card column 26, i.e,, a decimal 2,3,6, or 7) generates a pattern exactly similar to that of Symtry Routine 1, except that it is inverted, i.e., the first line of the Left Bank pattern appears as the last line of the image pattern.

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Appendix 1

Sample Set of 21 patterns generated by MATTY

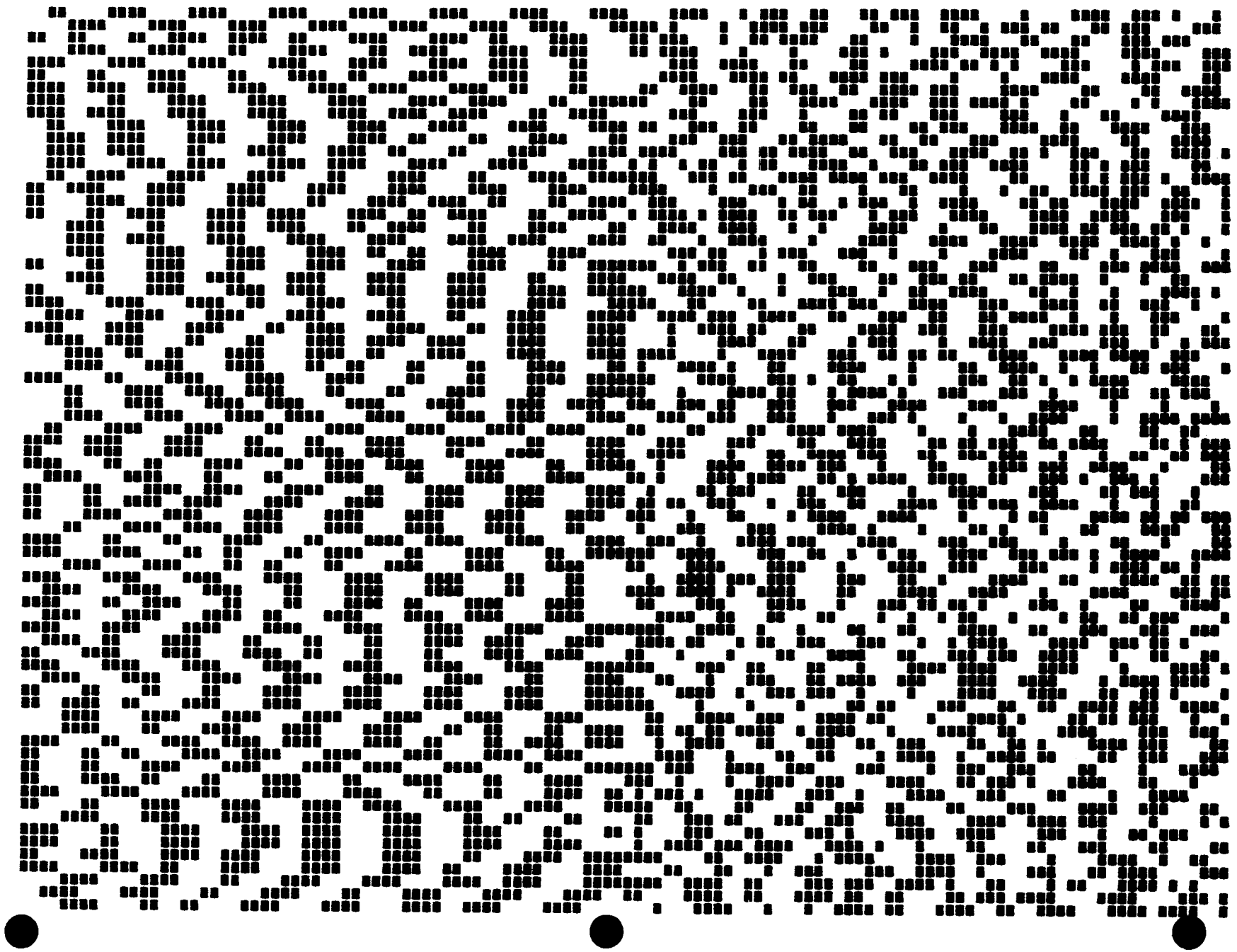
The table gives the probabilities for black and white runs of 1, 2, 3, and 4 cells. The Mean run length ($\bar{X}$) is the statistical average of both black and white runs. The sample set of patterns show selected possible changes in probability distributions of black and white runs.

PROBABILITY OF RUN LENGTHS FOR 21 SAMPLE PATTERNS
(120 x 72 character positions)

Right 1 2 3 4
$\bar{X}$ = 2.50 ¼ ¼ ¼ ¼

Pattern Number	LEFT SIDE Probabilities Black 1	Black 2	Black 3	Black 4	White 1	White 2	White 3	White 4	Mean X
3		.25		.75		.25		.75	3.50
6			.5	.5			.5	.5	3.50
11	.25			.75	.25			.75	3.25
15		.25	.25	.5		.25	.25	.5	3.25
16	.25		.25	.5	.25		.25	.5	3.00
26		.25	.5	.25		.25	.5	.25	3.00
37	.25	.25		.5	.25	.25		.5	2.75
42	.25		.5	.25	.25		.5	.25	2.75
54	.25	.25	.25	.25	.25	.25	.25	.25	2.50
120	.25	.25	.25	.25	.25	.25	.25	.25	2.50
125	.25		.75		.25		.75		2.50
130	.5			.5	.5			.5	2.50
146	.25	.5		.25	.25	.5		.25	2.25
151	.5		.25	.25	.5		.25	.25	2.25
157	.5	.25		.25	.5	.25		.25	2.00
167	.5		.5		.5		.5		2.00
173	.75			.25	.75			.25	1.75
181	.5	.25	.25		.5	.25	.25		1.75
182	.75		.25		.75		.25		1.50
185	.5	.5			.5	.5			1.50
186	.75	.25			.75	.25			1.25

14-2 0 1 1 4 -2 0 1 1 4
10-4 1 2 3 4 -4 1 2 3 4



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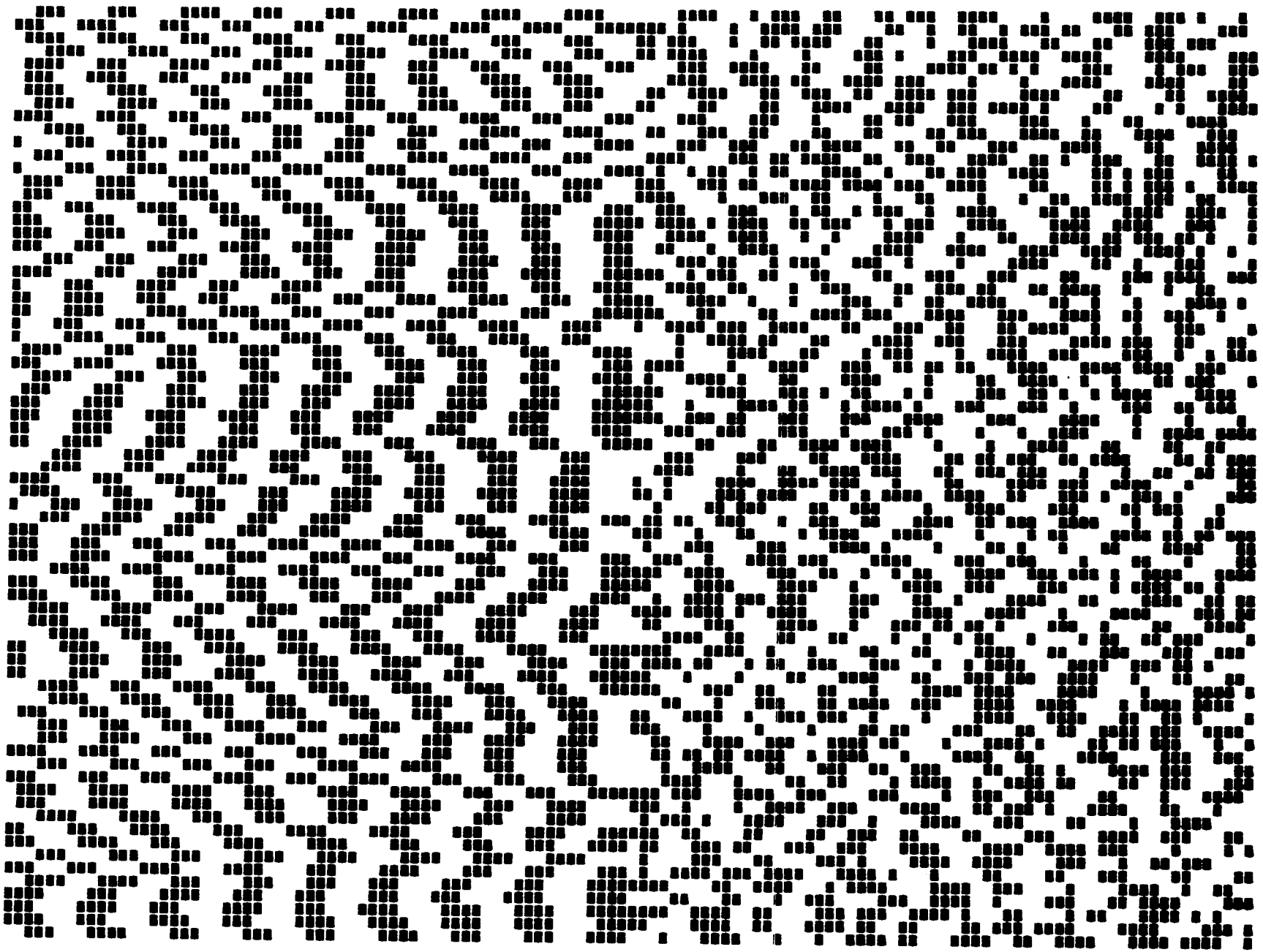
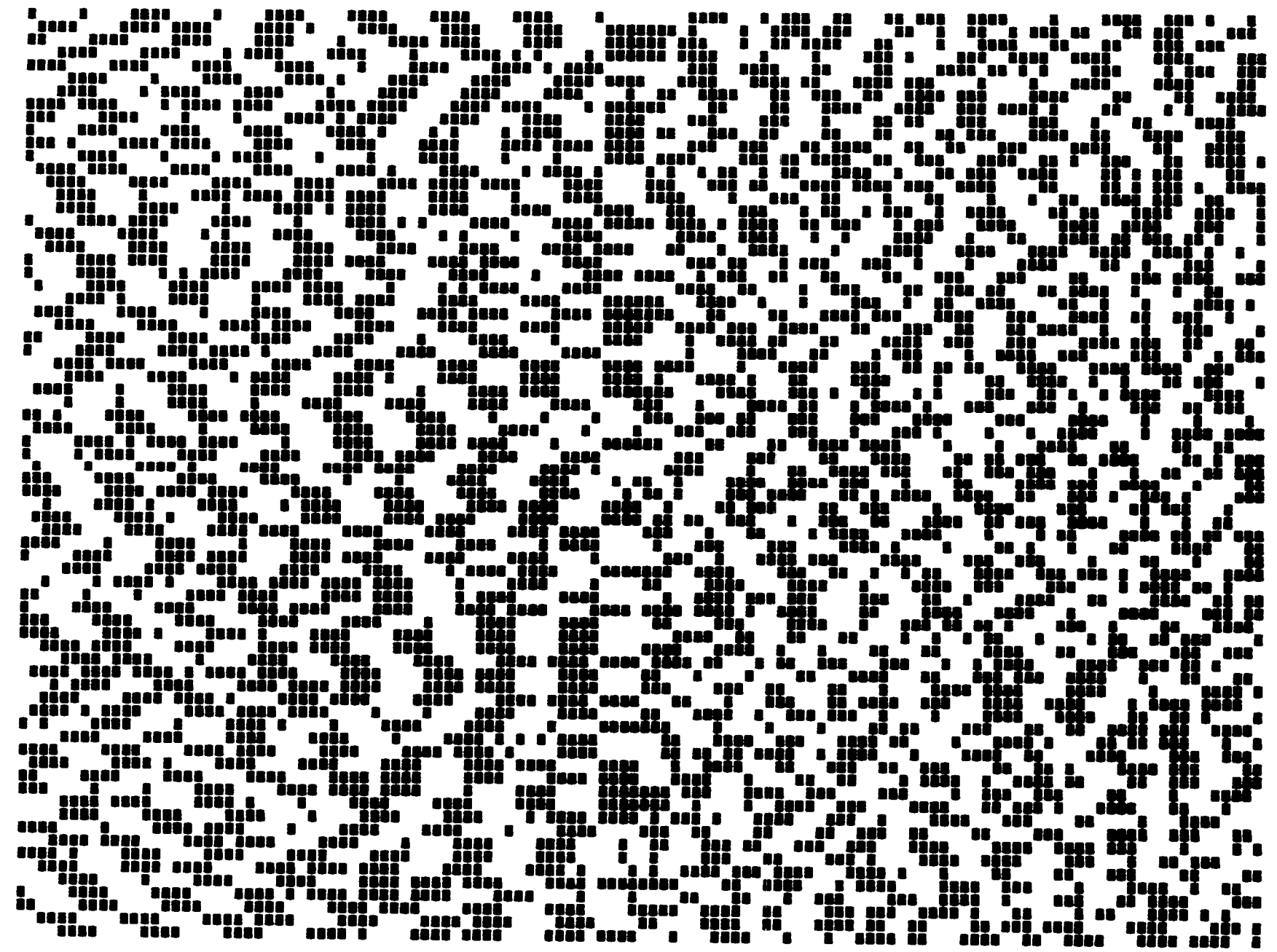
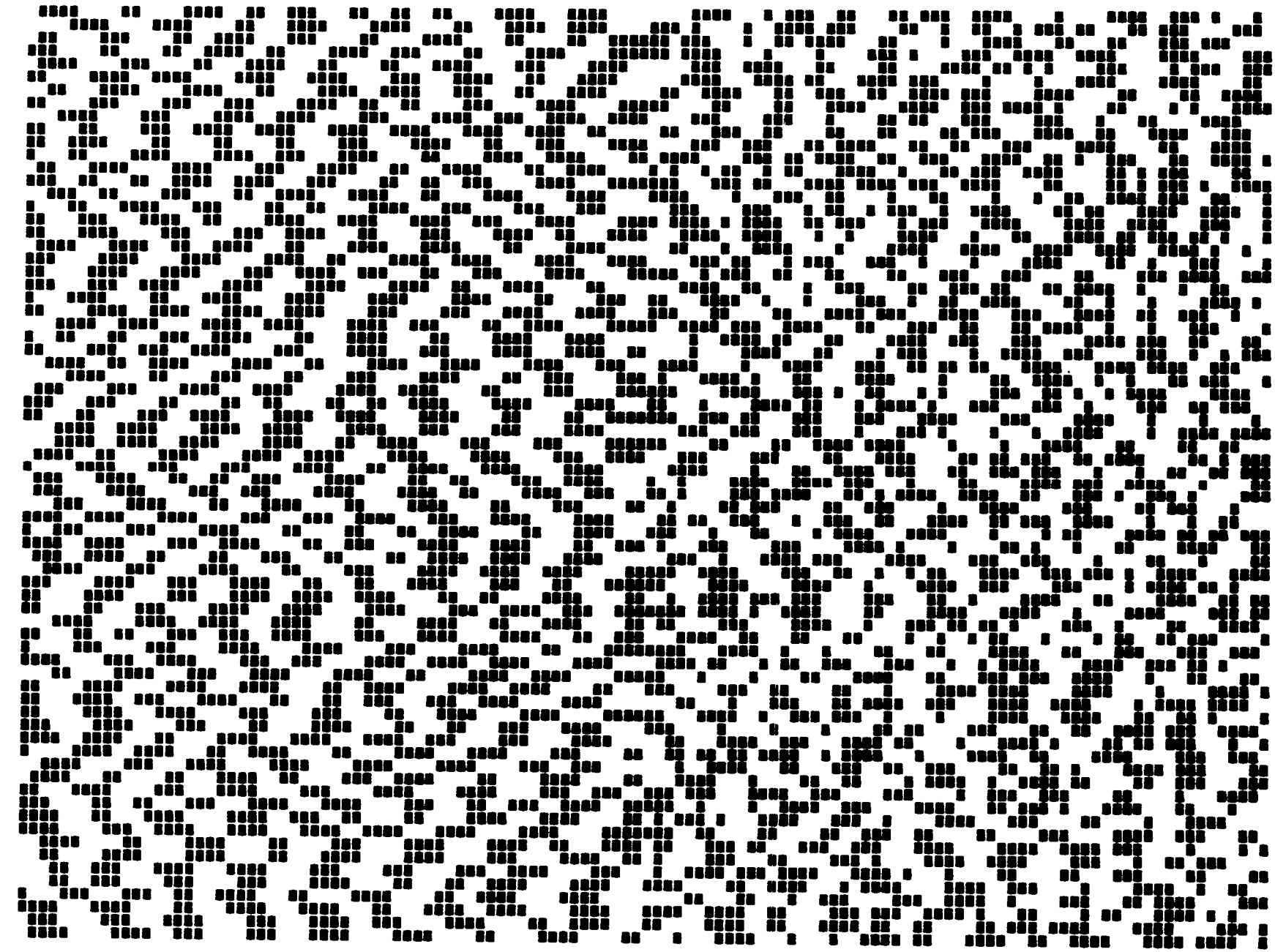
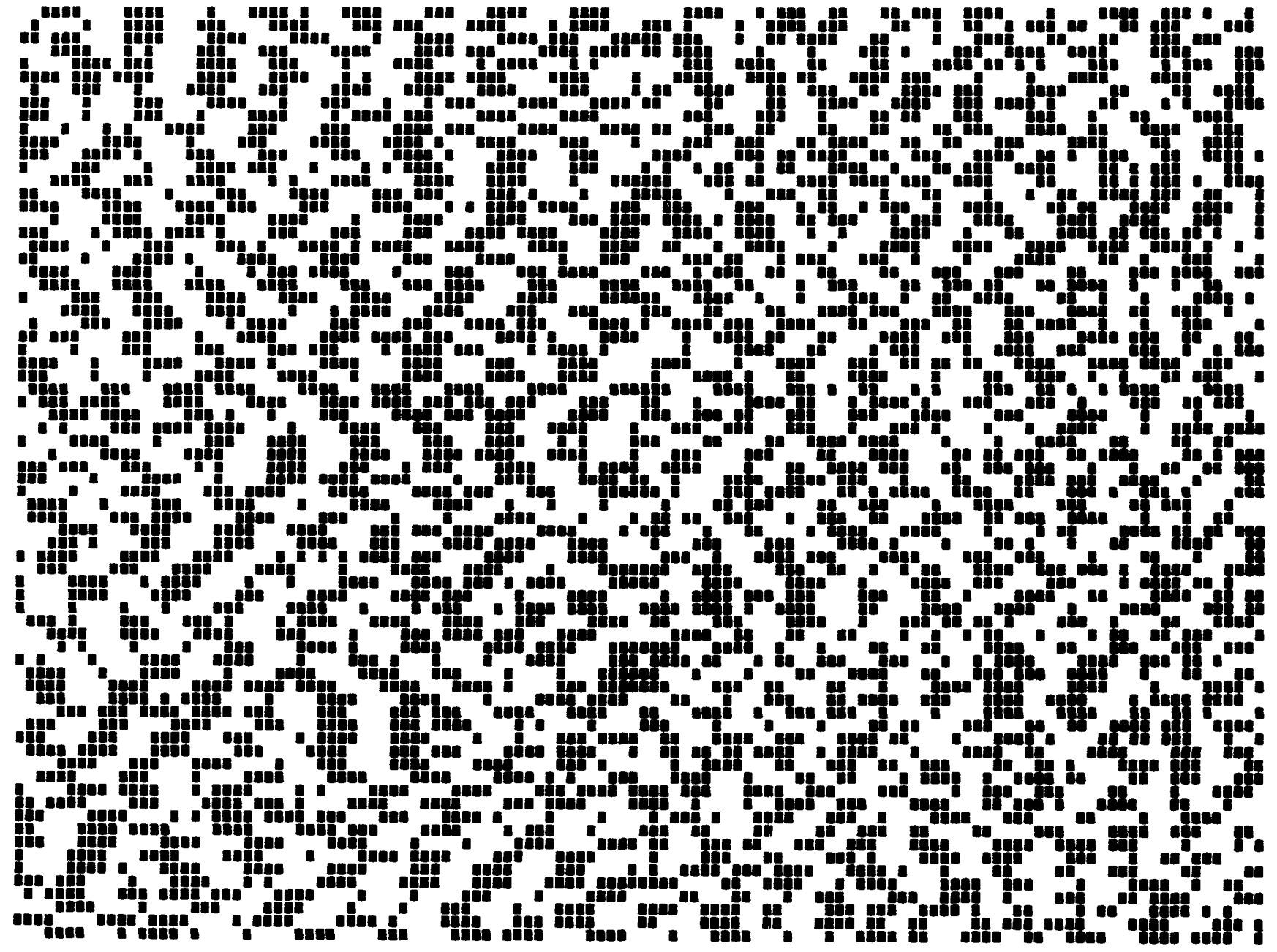
10-4 1 2 3 4 -4 1 2 3 4



13-2 1 1 1 4 -2 1 1 1 4
10-4 1 2 3 4 -4 1 2 3 4







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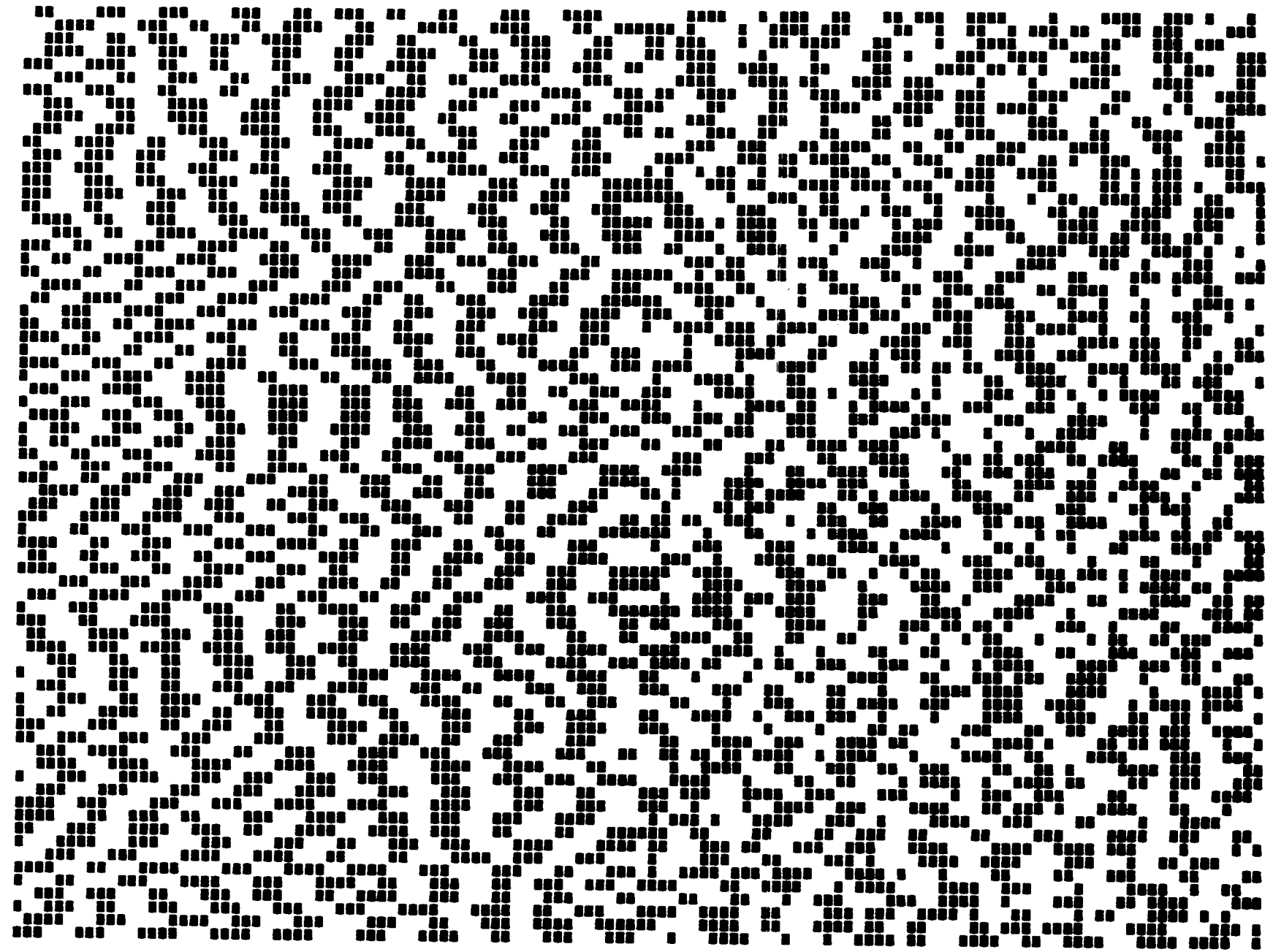
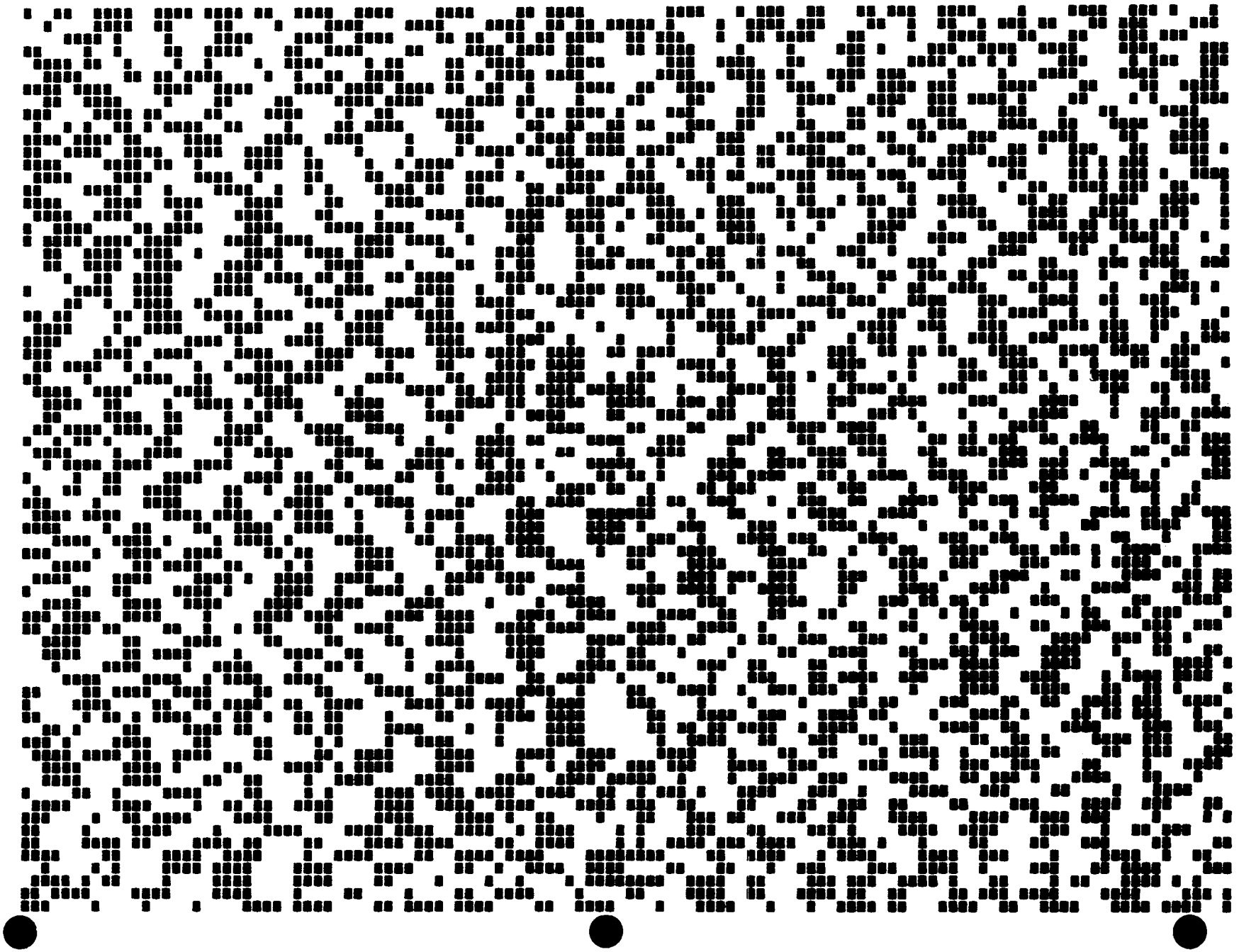
10-4 1 2 3 4 -4 1 2 3 4





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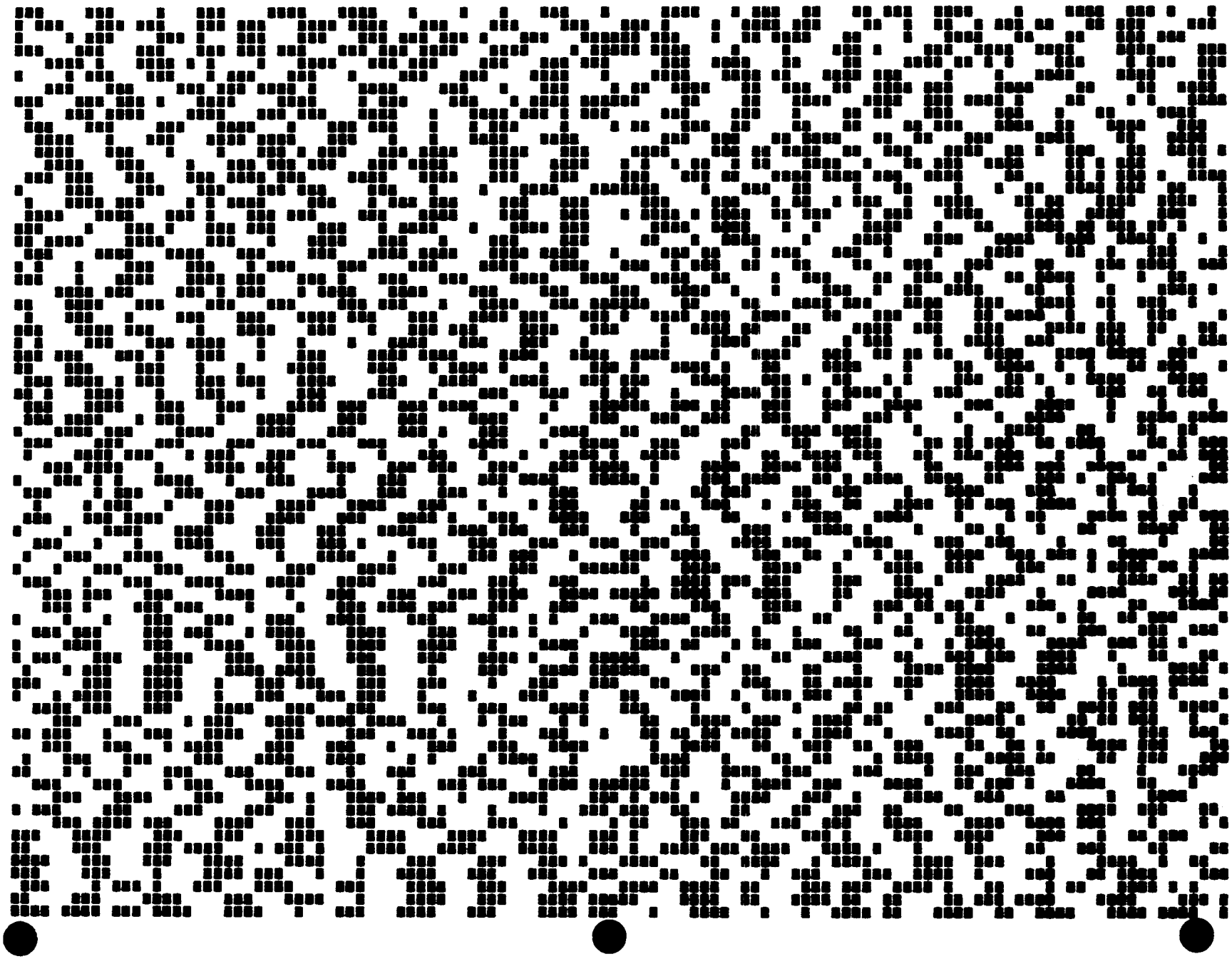

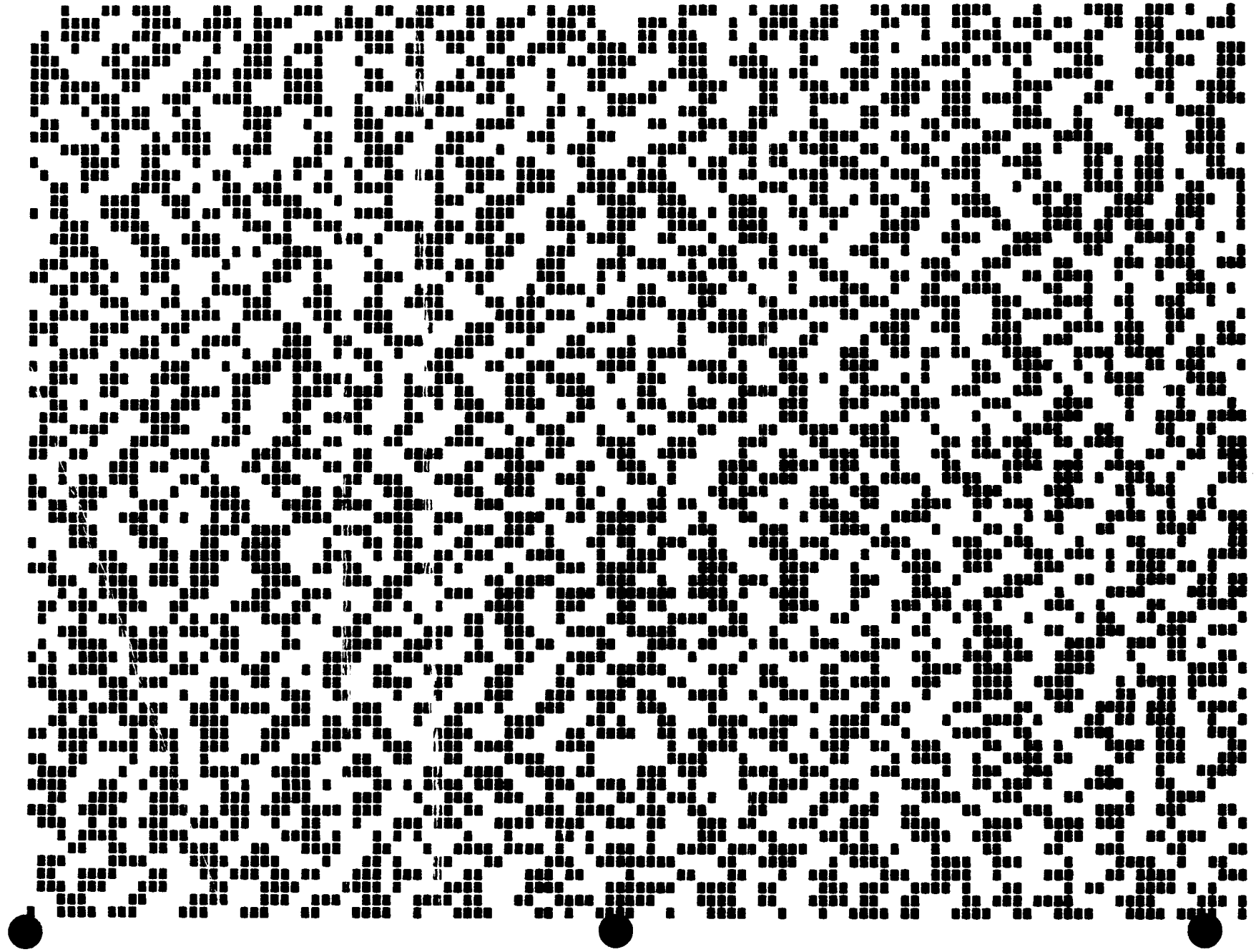

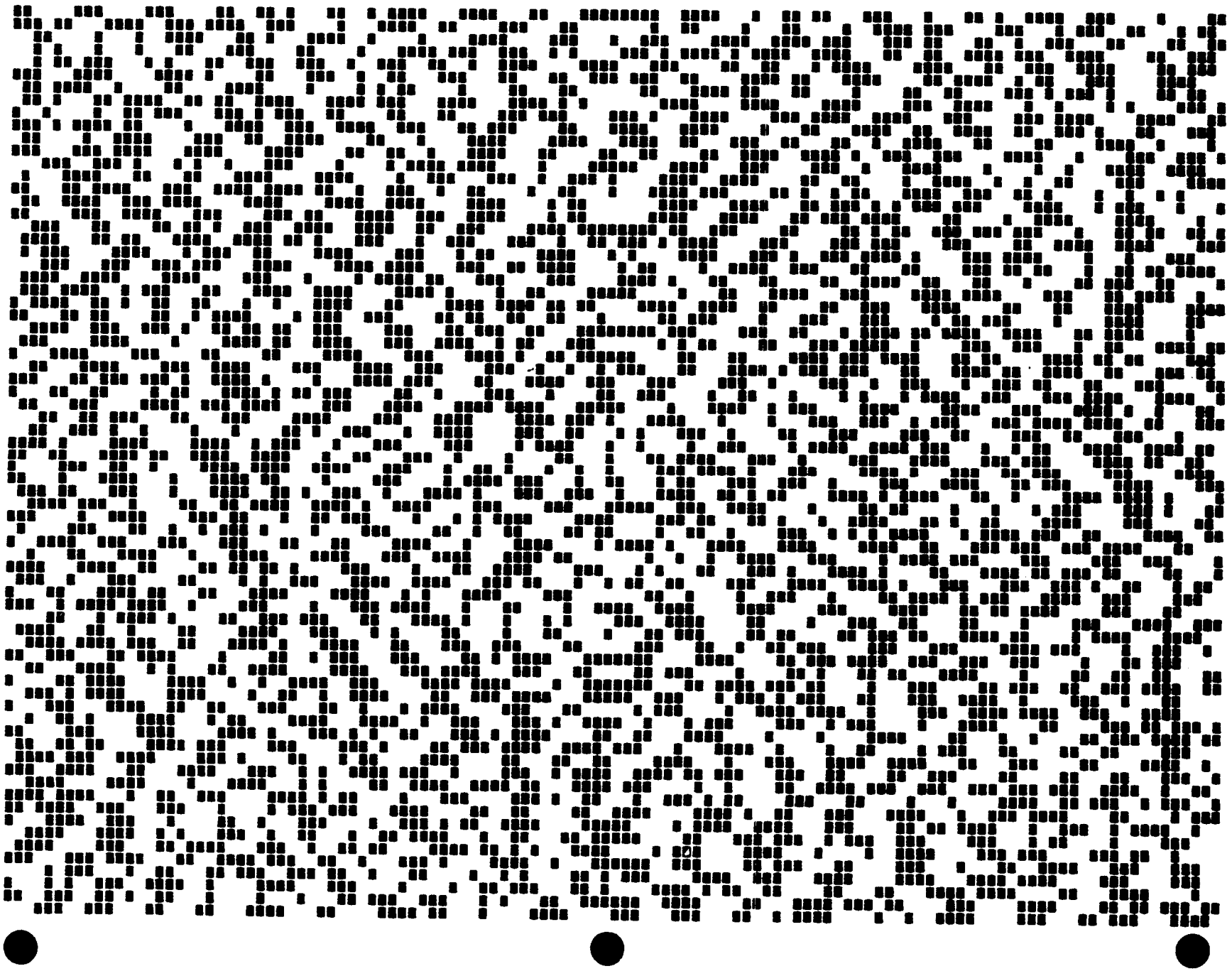

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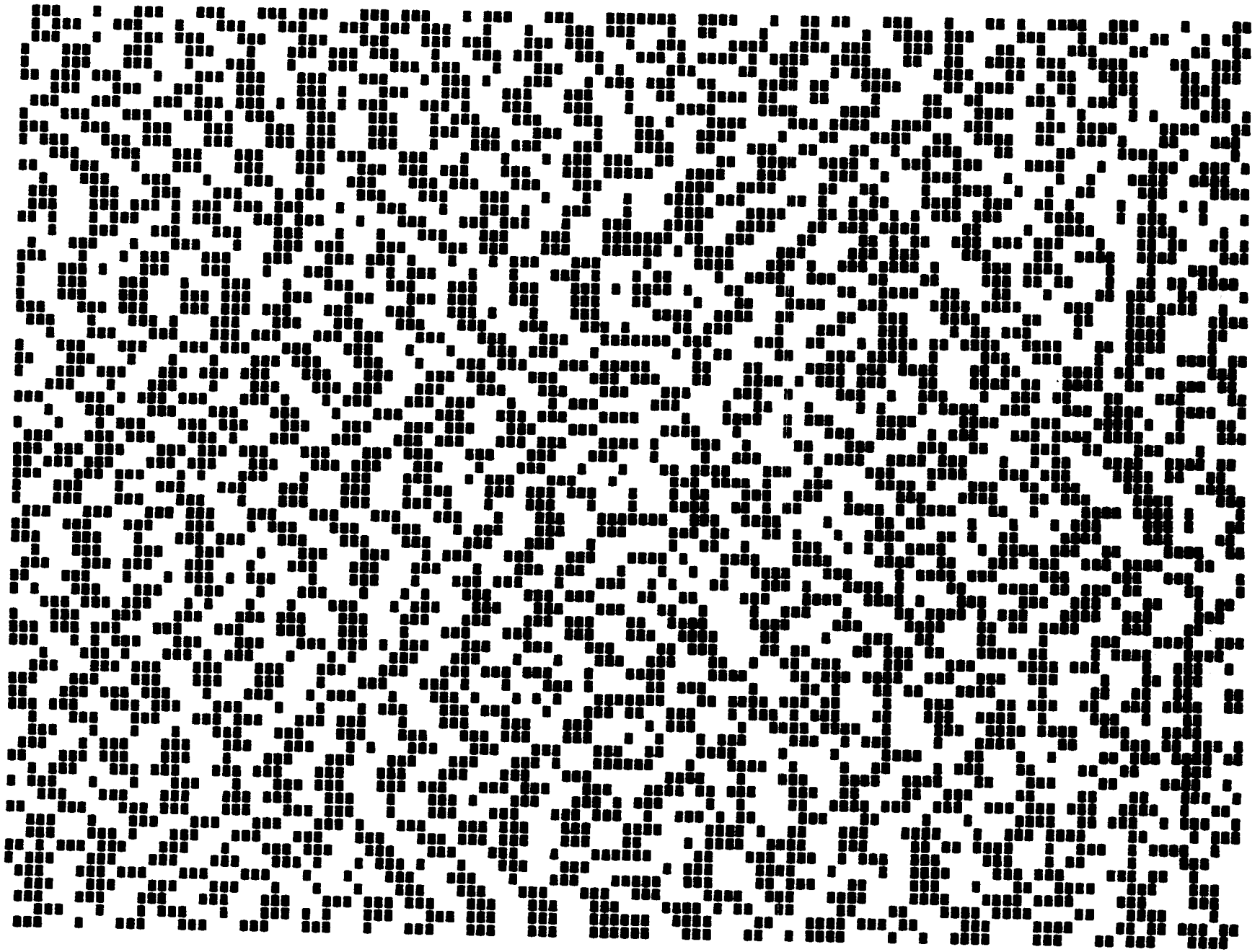
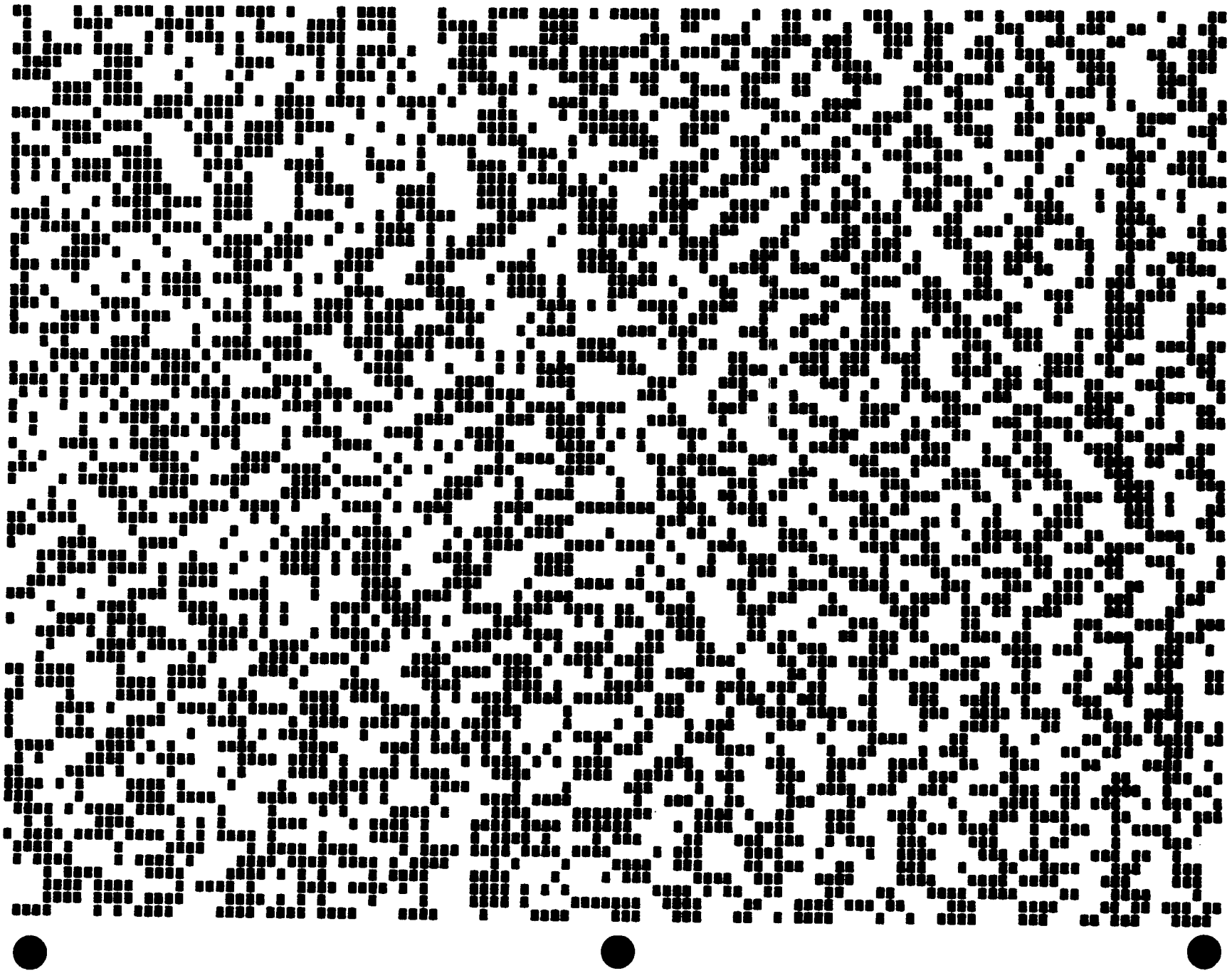
10-4 1 2 3 4 -4 1 2 3 4



10-2 2 2 2 4 -2 2 2 2 4
10-4 1 2 3 4 -4 1 2 3 4



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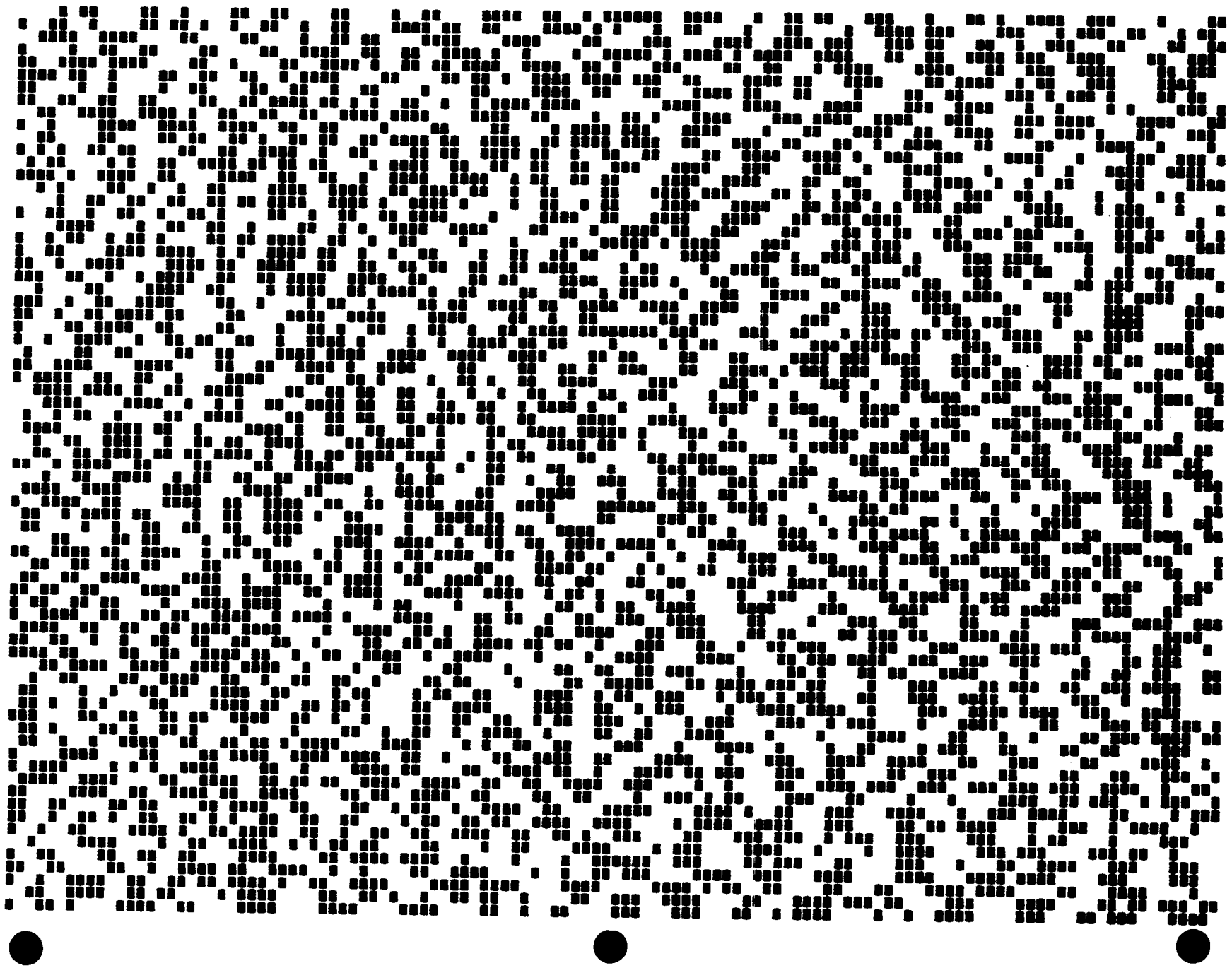
10-4 1 2 3 4 -4 1 2 3 4



9-1 2 2 3 4 -1 2 2 3 4
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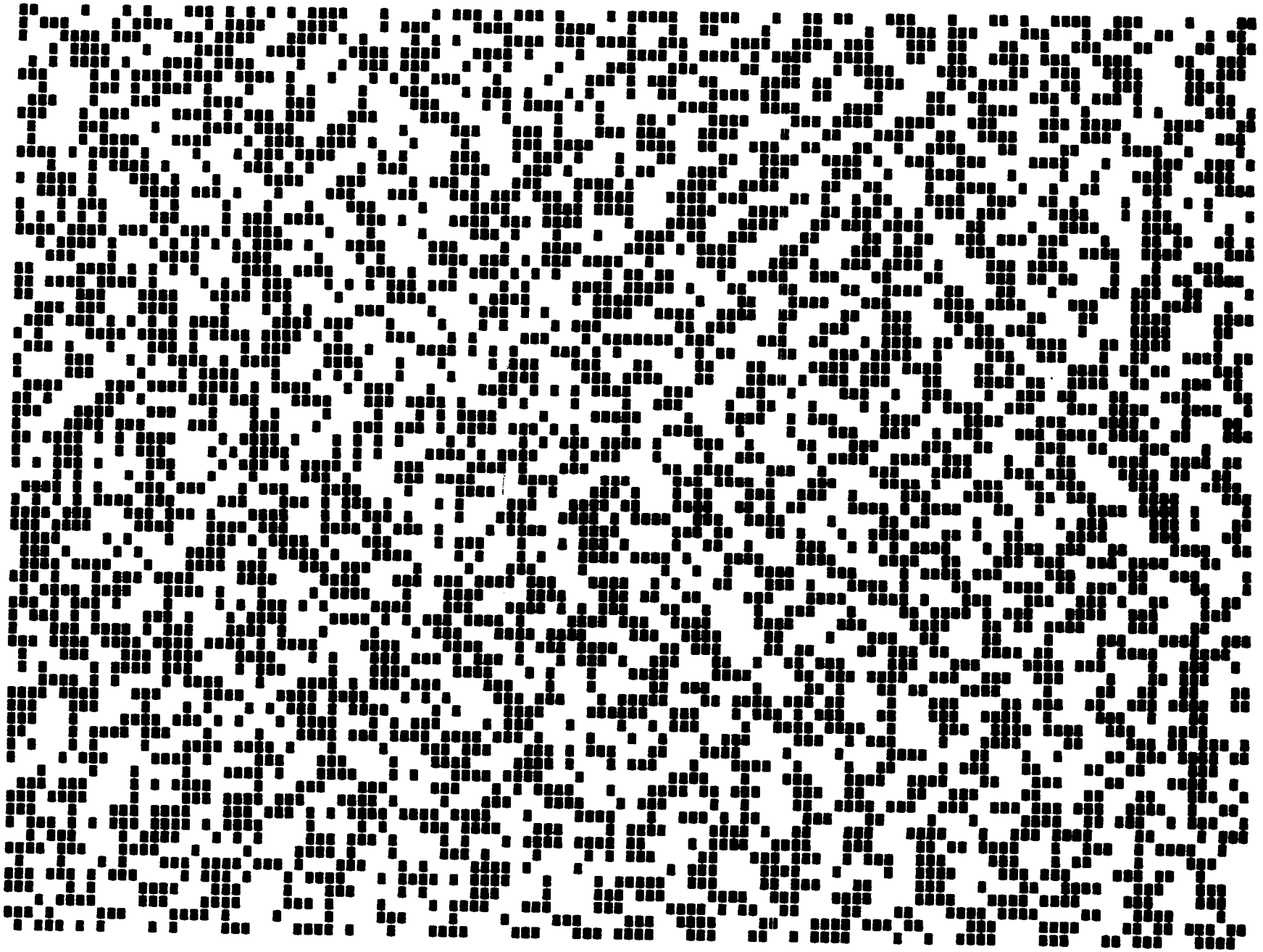
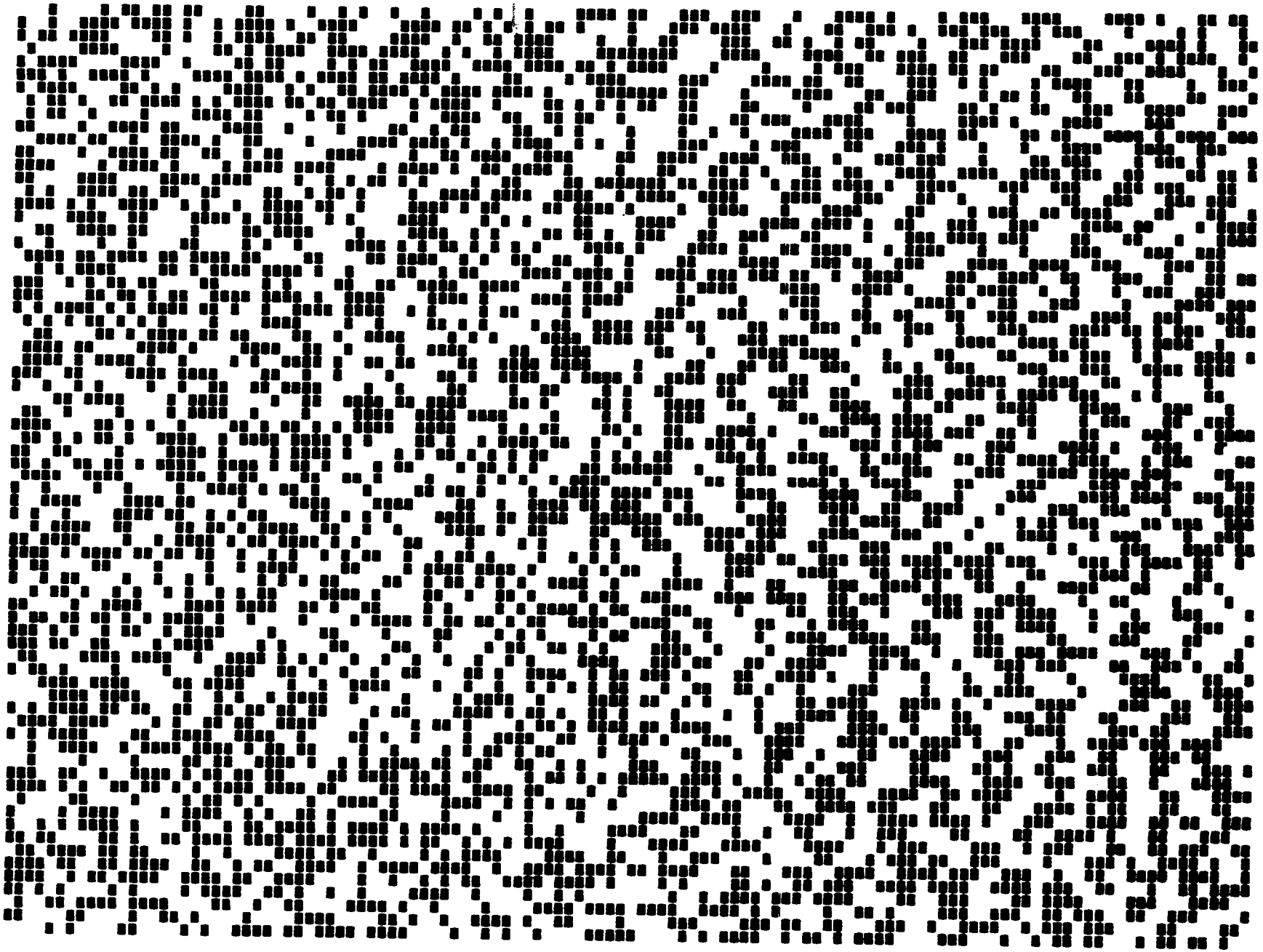
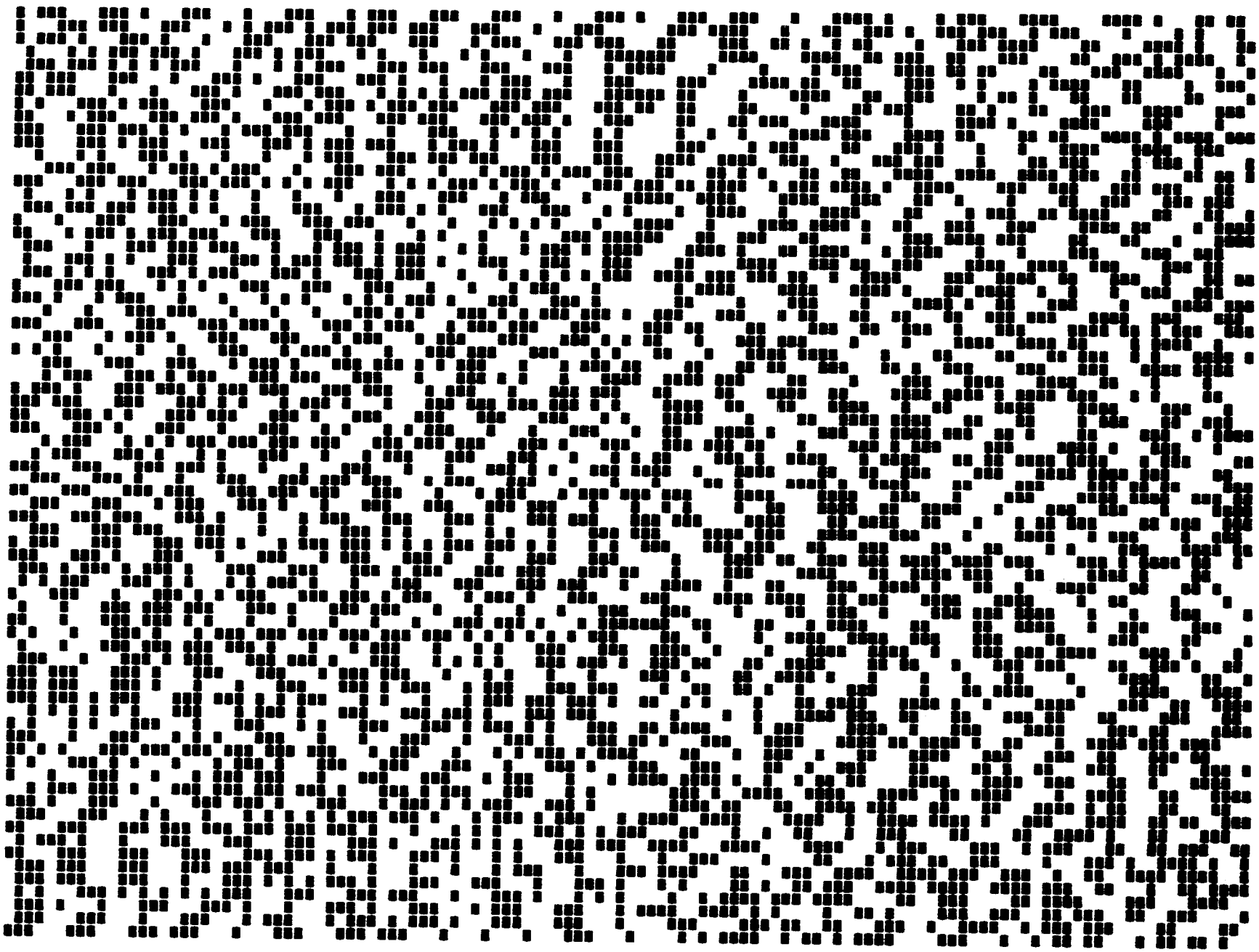
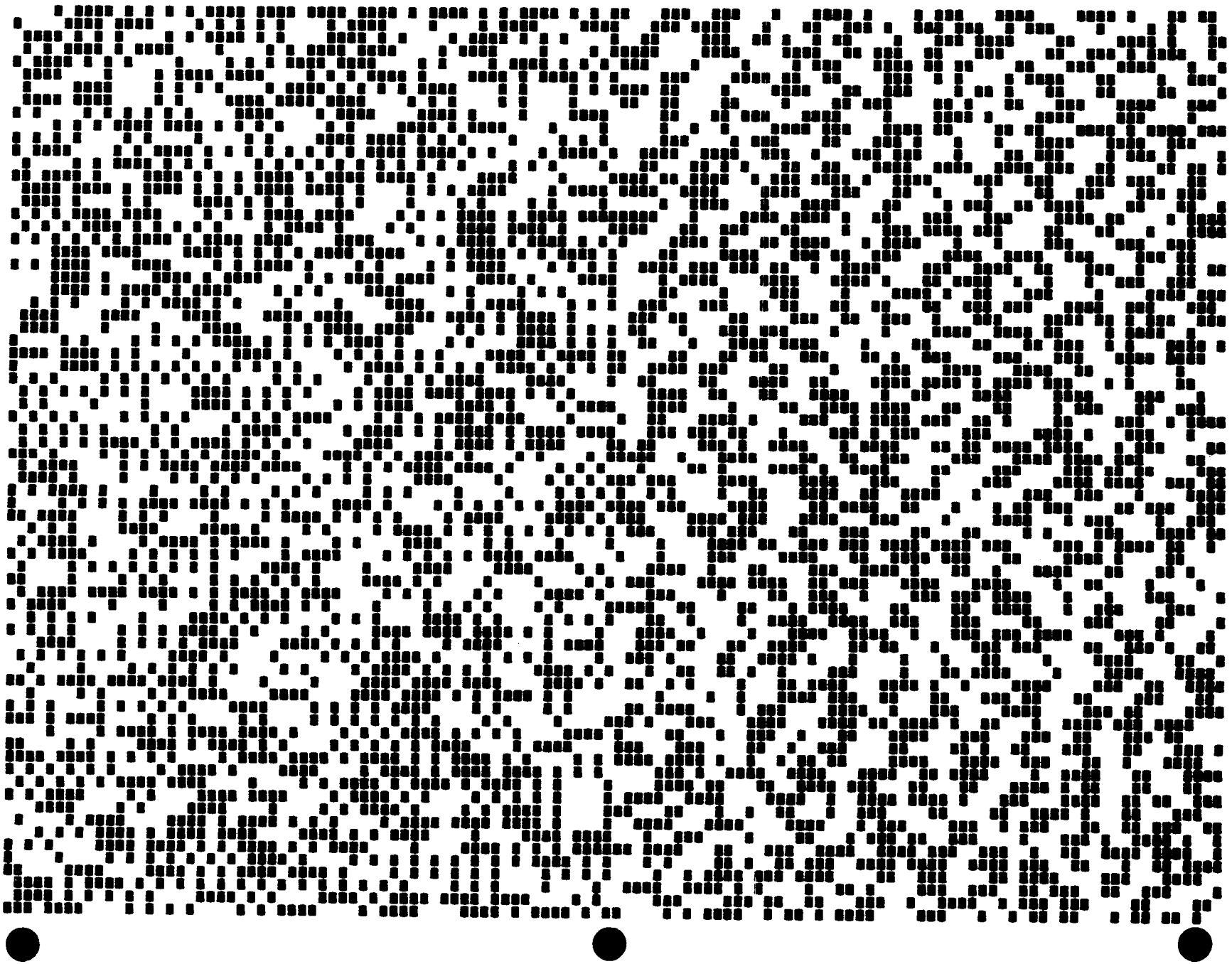


8-4	2 3 3 4	-4 2 3 3 4
10-4	1 2 3 4	-4 1 2 3 4

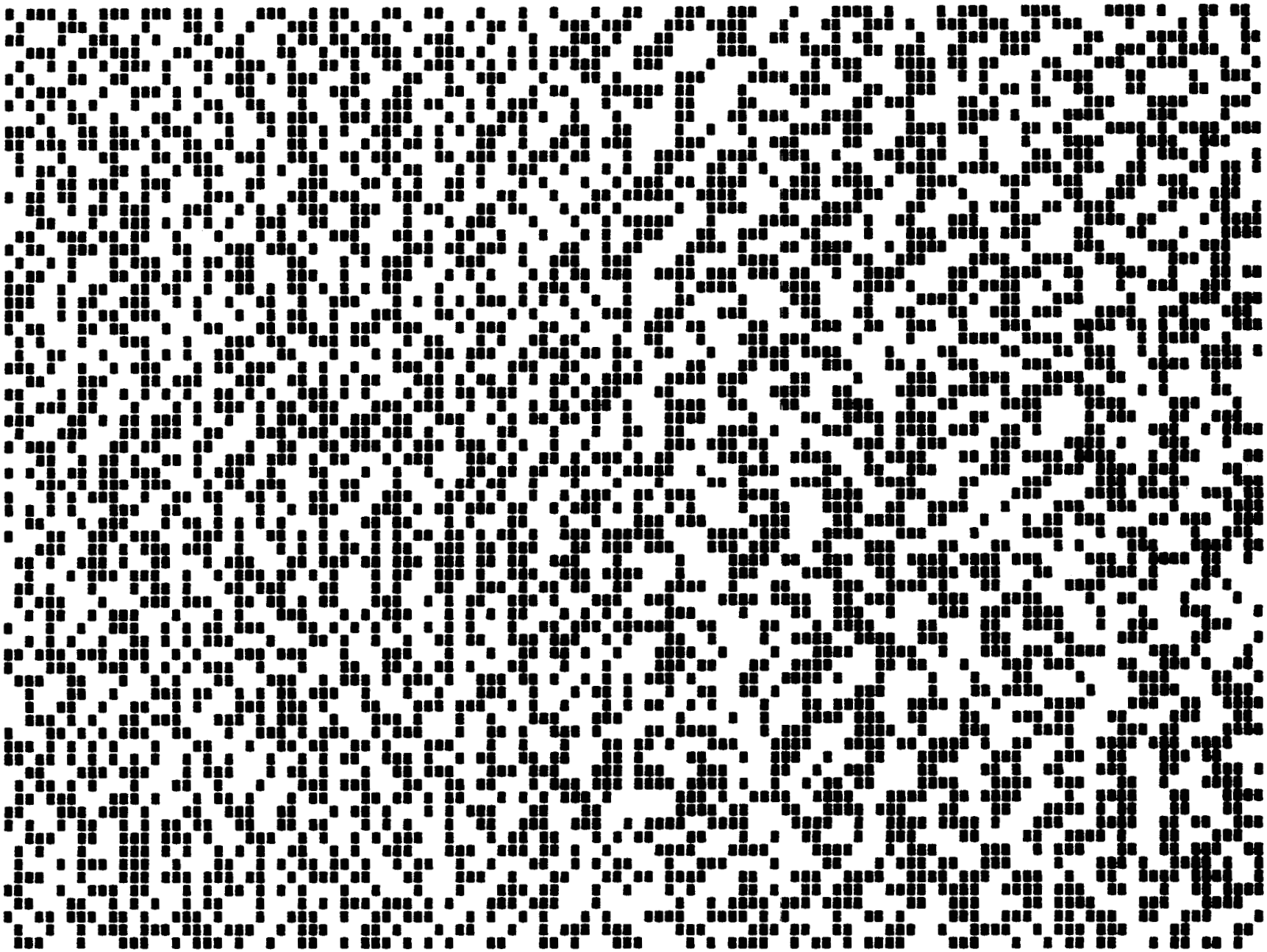


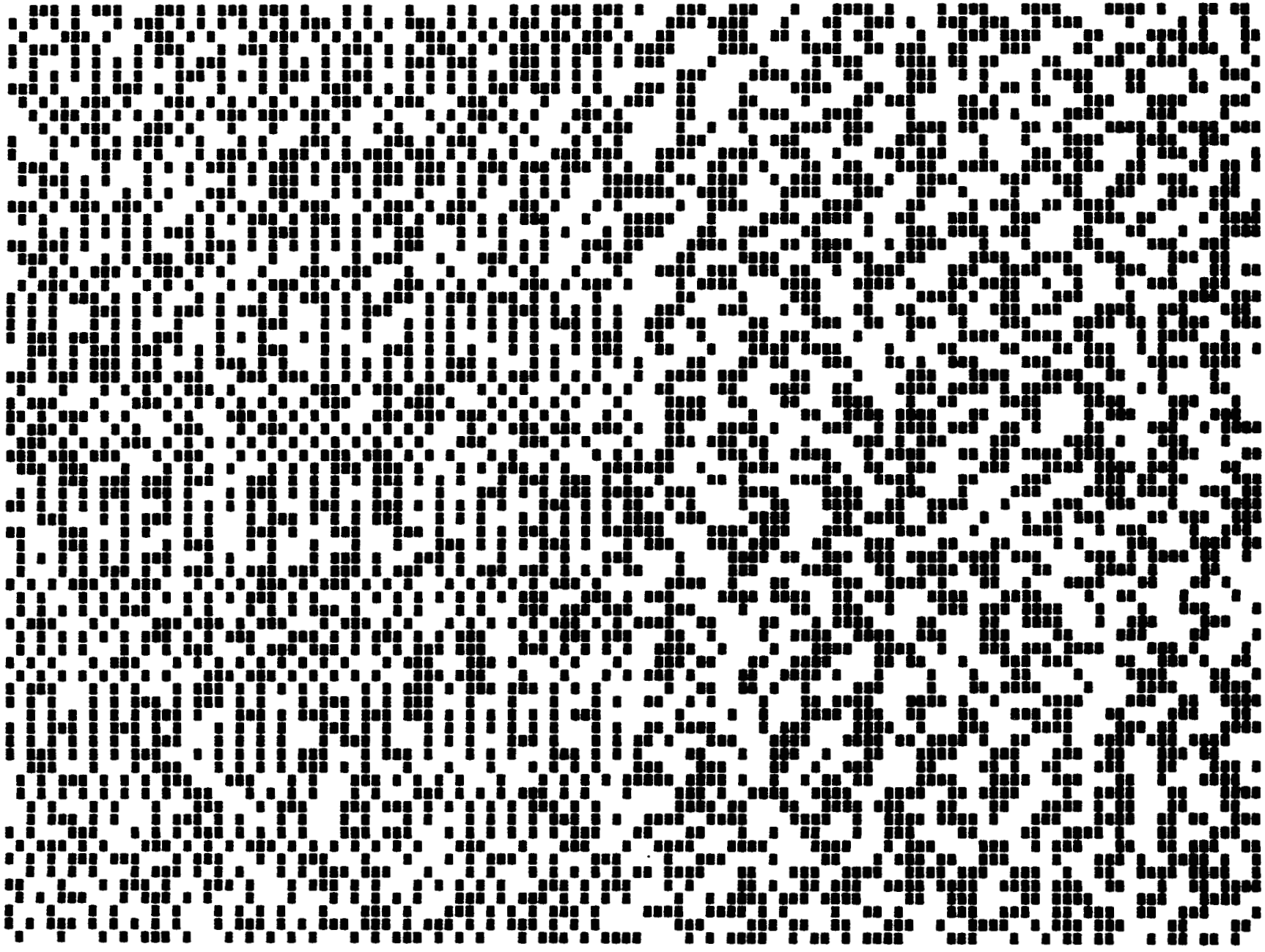
8-2	2 2 4 4	-2 2 2 4 4
10-4	1 2 3 4	-4 1 2 3 4



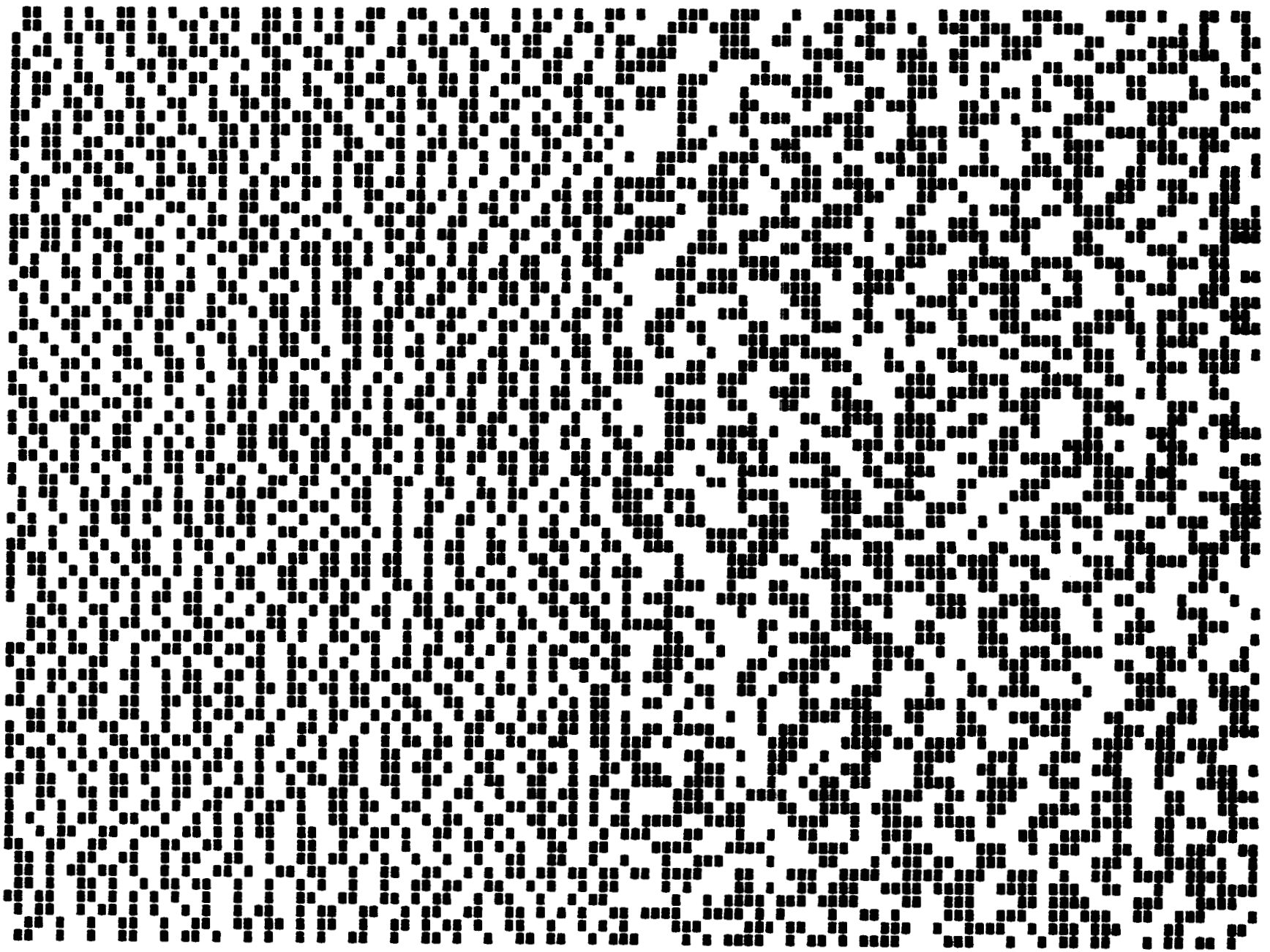


7-1 2 3 4 4 -1 2 3 4 4
10-4 1 2 3 4 -4 1 2 3 4

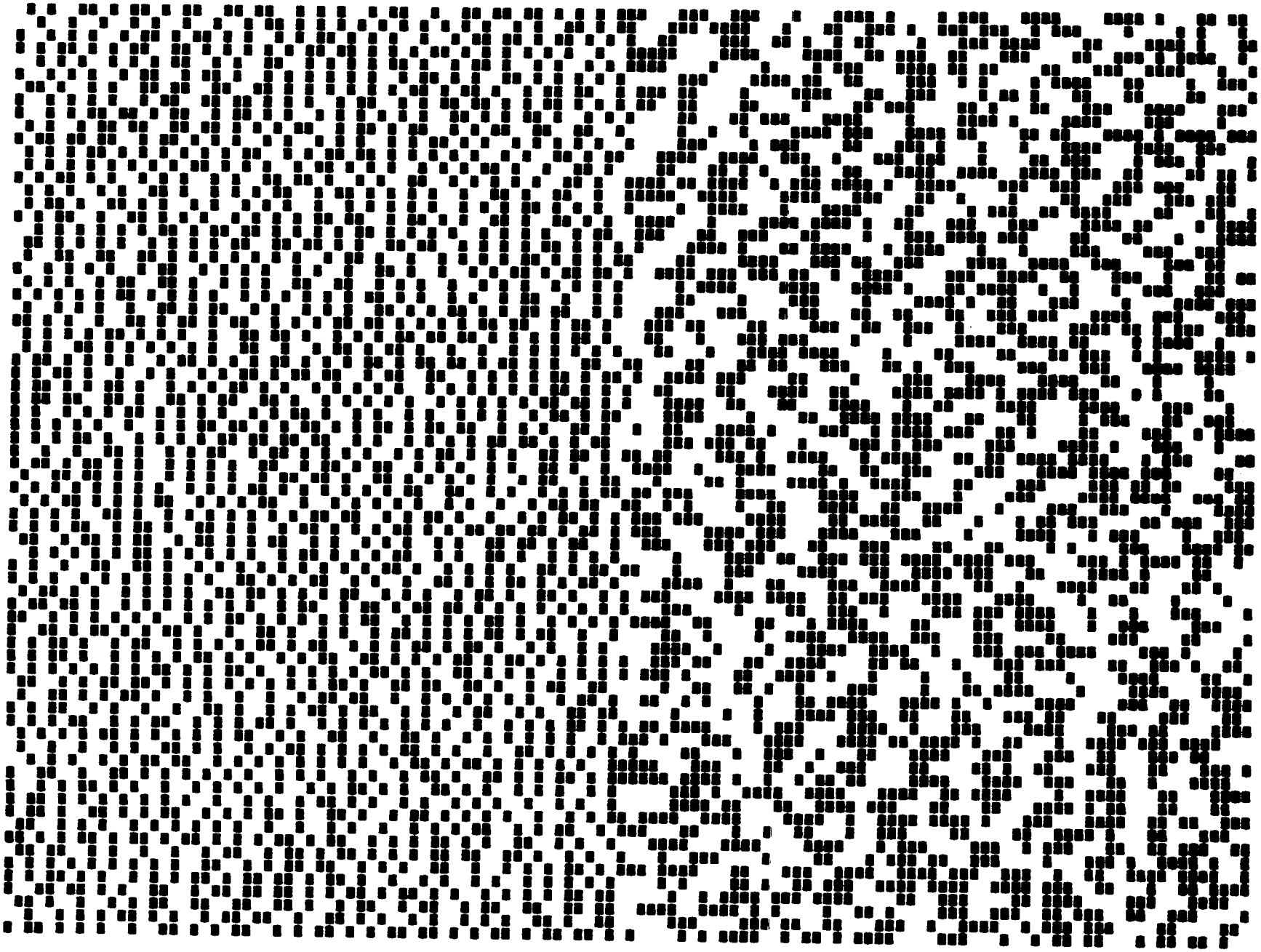




6-1 2 4 4 4 -1 2 4 4 4
10-4 1 2 3 4 -4 1 2 3 4



5-1 3 4 4 4 -1 3 4 4 4
10-4 1 2 3 4 -4 1 2 3 4



Appendix 2

Program Description

Following is a description of the MATTY program logic. The program and subroutines are described in sufficient detail to enable a programmer to modify it as desired and/or to write maximally efficient Sym Subroutines.

Program Description

Restrictions

(1) The output from this program will be on tapes, and these output tapes must be run on a 1401 system equipped with a 1403 (or equivalent) printer incorporating the overstrike feature.

(2) The input for this program must appear on tape, although the readin may be changed to cards by relatively minor modification of Main Program Block 1000. The logical number of the input tape (NTAPIN) is set in SUBROUTINE LIMITS.

(3) The output for this program will appear on tapes designated by the user on the N CTRL card. However, the program must be modified to properly identify the logical numbers of the system tapes in use at the user's site, or incorrect tape handling and/or damage to system tapes may result. In SUBROUTINE LIMITS, the Table TAP should be set for the machine unit equivalents of the logical tape numbers. (For example, if logical 8 is machine unit B3, then set TAP(8) = 2HB3. Unused or system tapes should be set equal to 6HILEGAL.) However, if the punch number and logical number differ, set the TAP vector positions corresponding to both the punch numbers and the logical tape number to the machine unit equivalent. (For example, if a 1 punch is converted to a logical 10, and the machine unit equivalent is B5, then TAP(1) and TAP(10) should both be set equal to B5, even though TAPE 1 is an 'illegal' tape.) NU should be set equal to the value of the logical number of the system print output tape, and KU to the value of the logical number of the punch output tape.

SUBROUTINE TAPNO should be modified as follows: JTAP should be set equal to JNC (which is equal to the number punched in column 35 or 36 of the N CTRL card) and then JNC set equal to 1 for all cases where the N CTRL card entries in column 35 or 36 are the same as the logical numbers of the tapes to be used, unless these are system tapes. For JNC values equal to system tape logical numbers, do not set JTAP, but set JNC equal to 2 if these are input tapes, or equal to 3 if these are output tapes. If it is desired that certain values in the N CTRL card columns not equal the logical number (as, if it is desired that a 1 punch equal the logical number 10), these should be separately set (by setting JTAP to the desired value) and JNC set to 1 before executing a RETURN.

SUBROUTINE FINISH should be modified to process only non-system tapes.

Program Description, Main Program

(1) The START OF MATTY, BLOCK NUMBER 0000, is used for the main program dimension and common statements and for the definition of Pass variables (those variables which are not reset between Jobs). SUBROUTINE LIMITS sets a number of Pass variables whose definition depends upon local system usage (hence, to change the value of these variables it is only necessary to recompile the subroutine). Of these, JT is the maximum number of MATTS which may be written on any one Job; TAP is the table which converts the logical tape numbers to the actual unit tape numbers for on-line operator instructions; M2 is an adjustment factor for the page count for each Job; M3 is the number of headings per page at 8 lines per inch; JLL is the maximum number of MATT lines which can be printed on off-system tapes (≤ 80); NTAPIN is assigned the logical number of the system (or other) data input tape; NU and KU are assigned the logical numbers for the system Print and Punch Tapes, respectively. A program check is made to see if SENSE SWITCH 5 is down; if it is, the program prints an on-line request to set all SENSE SWITCHES up, sets a flag, and pauses.

The NC Vector is dimensioned for 80 locations, making 15 positions (53-69, 72-79) available for future program modifications. The Vector SC which precedes NC in COMMON storage is effectively equivalenced to NC by giving it a dimension of 0. (The SC form is used for the Boolean expressions, which require a Floating Point variable form.) NC (or SC) 80 should not be used, as in certain special conditions it is used by the IBNK Matrix; NC (or SC) 70 is used by SUBROUTINE SYMTRY; and NC (or SC) 71 is used for the printout of the random numbers in MATT Heads.

(2) The INITIAL RESET, READIN, AND READOUT, BLOCK NUMBER 1000 defines most of the important program Job variables, and procedes to read the first (or next) Job data. The first card is checked to see if it is a DATA END card; if it is not, it is checked to see if it is an N Control (N CTRL) Card and, if it is, it is read in. (The somewhat complicated method of reading the N CTRL card is to avoid destroying the existing N CTRL data if the card at

the N CTRL station is not an N CTRL card, and to avoid an EXEM Kickout if the FOGVEC card is at the N CTRL station, and alphabetic data are in the numeric field. The formats of the data cards are such that an EXEM Kickout cannot occur no matter how the cards are arranged, providing they do not contain illegal data.) After the N CTRL card is read, the Left Bank Probability Data are read. The program assumes that the first thirteen P DATA cards are for the Left Bank unless a 77 appears in columns 65-66, in which case it recognizes that card to be the last P DATA card for the Left Bank. The next thirteen cards are assigned to the Right Bank, unless SUBROUTINE SYMTRY is called or a 99 appears in columns 65-66, in which case the program immediately goes to the next station. If this is the first Job, or the FOGVEC characters previously read in were defective, or if the N CTRL card so directs, the program now attempts to read a FOGVEC card (and the flag NOFOGV is set to 0). Finally, if this is the first job, or the RANDNO number previously read in was defective, or if the N CTRL card so directs, the program now attempts to read a RANDNO card (and the flag NORAND is set to 0). If a new random number is read, the operational random number, ORA, is set equal to the value of the new random number, ORAN, otherwise ORAN is set equal to the existing value of ORA, which at this time contains the last random number generated on the previous Job.

If at any point in the readin, an incorrect card is sensed at some station, the Job is Abruptly Terminated and the program goes on to the next Job (unless the N CTRL card calls for a Kickout, in which case the Pass is terminated). A DATA END card at any point terminates the Pass, and each N CTRL card is read as the beginning of a new Job, even if it was the cause of the termination of the previous Job.

NC(35) and NC(36) are checked to see if off-system tapes are requested for either the printed or the punched output. If not, the tape check and set section is bypassed and NTAPOU and KTAPOU retain their original setting, which is for the system print and punch tapes respectively (i.e., NU and KU which are set to logical 6 and 7, respectively, at this site). If NC(35) contains any number other than zero, it is assumed to be a request for an

off-system tape for printed output and SUBROUTINE TAPNO is called. A one is converted to logical ten (since logical one at this site is the IBSYS library tape); five, six, and seven (the local system tapes) are rejected, and the flag WRI is set to the appropriate class of error (on the return to the Main Program). WRI is later checked and initiates an Error Routine if it is not zero. A check is also made to see that the assigned number has not previously been used nor is presently requested for punched output (if it has or is, an error is signaled and WRI is appropriately set).

Within these constraints, the printed output is assigned to the tape number contained in NC(35). If NC(36) contains any number other than zero, similar adjustments and checks are made before allocating that number for the punched output tape. If any legal off-system tape is requested, SUBROUTINE TAPOU generates the appropriate on-line operator instructions and the program pauses to permit the operator to mount tapes. If the tape request was illegal, all output appears on the system tape (TAPOU is not called), but an on-line message notes the Job number and states that an error occurred, without causing a pause (this is accomplished in Subroutine WRITE): on-line error messages are printed only in the event of an Abrupt Program Termination, or if an off-system tape was requested for the Job. In the event of any error occurring after the Readin phase, the error flag NOEXEC is set and the program continues, but the MATT generation and printout are suppressed. Thus, data errors are normally detected on one pass.

Unless the Initial Output is suppressed by the N CTRL card, the program procedes to write a copy of all of the data onto the assigned tape: blank N CTRL and P DATA cards are not listed. If the system printed output tape is being used, the maximum number of MATT lines is set to 50; if an off-system tape is being used, the maximum number of MATT lines is set to the value JLL defined in SUBROUTINE LIMITS. M5 is set equal to the total number of pages of Initial Output and Final Output, which depends upon N CTRL coding.

(3) The coding for IBNK(A,B,C) is as follows: A represents the P DATA Cards read into the IBNK matrix and is equal to the position of the card for Left Bank cards,

e.g., the third card is entered at IBNK(3,B,C). For the Right Bank, A equals the position of the card plus 13. Thus, the second card read into the right half of IBNK is entered at IBNK(15,B,C). MED is the index controlling the Right Bank entries and MEA is the index controlling Left Bank entries, although since MEA is also the index used in the actual MATT Generation, MEA is set to MED prior to the generation of the Right Bank MATT.

B represents the number of the distribution in a particular A entry, hence may vary from one to five, depending upon the number of distributions entered on the P DATA card read into A. The index for the Right Bank Black Run Length Distributions is normally NX and for the Right Bank White Run Length Distributions is normally NY (although both distributions are taken from the same A entry, since the Means of the Black and White Run Lengths are normally equal); the index for the Left Bank Black Run Length Distributions is normally LX and for the Left Bank White Distribution is normally LY. (Although, again, since LX and LY are also used in the MATT Generation, LX is set equal to NX and LY to NY prior to the generation of the Right Bank MATT.)

C represents the run length, i.e., the number of adjacent print positions of either blanks or overstruck characters. Thus, the adjusted value of IBNK(4,2,3) is equal to the probability of a run length of 3 for distribution 2 on Left Bank P DATA card 4. The LL Vector contains the maximum number of distributions for the corresponding IBNK entry. That is, if LL(12) contains a 3, then the twelfth P DATA card read into IBNK contains 3 distributions (and, hence, IBNK (12,4,C) and IBNK(12,5,C) are empty for all values of C from one to four).

(4) The LL Vector values are computed in LL VECTOR INITIALIZATION - PART I, BLOCK NUMBER 2000. The computation is performed by searching for the first set of distribution numbers whose sum is 0, beginning with Distribution One (P DATA card columns 1-4). However, if the entry for the Mean (P DATA card columns 21-22)

is 0, the distributions are not checked and the LL value for that IBNK entry is set to 0.

If SUBROUTINE SYMTRY is called or any N CTRL Takeover is indicated by the N CTRL card, LL VECTOR INITIALIZATION - PART II, BLOCK NUMBER 2500, begins by writing a copy of the LL Vector values on the assigned tape. If an N CTRL Takeover is indicated for the Left Bank, NC(1) through NC(13) (from N CTRL card columns 1-13) are checked to see if they are equal to or less than the corresponding LL Vector value. (A 7 us interpreted as a 0, i.e., use no distributions from this location, hence, it is always accepted.) If the N CTRL takeover is indicated for the Right Bank, a similar check is made of the values of NC(14) through NC(26) (from N CTRL card columns 14-26). Therefore, if SUBROUTINE SYMTRY is called and a Right Bank N CTRL Takeover is also indicated, an error condition may result since all of the Right Bank LL values have been set to 0. If the Initial Output is not suppressed, or if an error has occurred, N CTRL card columns 1-26 are written on the assigned tape (it should be noted that the error output cannot be suppressed), unless the entire first phase of LL VECTOR INITIALIZATION - Part II has been bypassed because neither SUBROUTINE SYMTRY is called nor any N CTRL Takeover is indicated.

The second phase of this program block begins with a check of the flag WRI to see if any tape assignment error has occurred, and if it has, the Error Routine for that condition is initiated at this point. Then, if a FOGVEC card has been read on this Job, a check is made for blank columns to the left of any character in the Left Bank word (FOGVEC card columns 41-48) or the Right Bank word (columns 49-56). A blank first column automatically signals an error. If an error is indicated at any point in a word, all blank columns are listed in the Error Output, otherwise, blanks to the right are ignored. A further check is made to see that the number of overstrike characters for the two words are equal, and the overstrike counter (MOP) is set equal to the number of characters to be overstruck. (If the number of overstrike characters in the two words are unequal and if the N CTRL card does not call for this condition, an error is signaled.)

If no error has been indicated, the NOFOGV flag is set and all subsequent Jobs do not attempt to read in a FOGVEC card (unless so instructed by the N CTRL card); if an error has occurred, the flag is not set and all subsequent Jobs until the next Job with a FOGVEC card are Abruptly Terminated. The Random number is checked to see if it is odd, and if it is, the NORAND flag is set. The NORAND flag operates analogously with respect to the RANDNO card as the NOFOGV flag with respect to the FOGVEC card.

Finally, if NC(51) contains a 999, it is set equal to JT, which is the maximum number of MATTS permitted on any one Job. If NC(51) does not contain a 999, but is positive, it is checked to see that it is $\leq$ JT (if not, an error is signaled). If NC(51) is $\leq$ 0, it is set equal to 4.

(5) If the N CTRL card so instructs, the entire CHECK ROUTINE FOR PROBABILITY TABLE DATA, BLOCK NUMBER 3000, is bypassed. The N CTRL card can also be used to suppress the check of the Right Bank Probability Data only (this check is automatically suppressed if SUBROUTINE SYMTRY is called), and/or the check to determine if the distribution numbers cumulate to 4. (The MATT generator is constructed so that probabilities which are multiples of 1/3 can be used, by making the probability numbers cumulate to 3. If numbers larger than 4 are used, they will be read as 4.) In the main test routine, the probability numbers are checked to see if they average to the Mean, and if they cumulate to the right.

(6) CONTROLLED MATT SIZE, BLOCK NUMBER 4000, sets all of the parameters for the generation of the MATT. If NC(33) is less than 6, the margins are arbitrarily set to the limits 1,60, and 120, respectively, and the contents of N CTRL card columns 42-47 ignored. If NC(33) equals 6 or more, the margins are taken from those columns of the N CTRL card, and if NC(33) is greater than 6, the margins are increased by 100 as indicated. The Right Margin is checked to see that it is equal to or less than 120, the Intermargin that it is less than the Right Margin and greater than or equal to the Left Margin, and the Left Margin that it is greater than 0. For

example, if the margina are set at 31,30,30 (Right, Left, and Inter), only a single column of each Bank will be generated, 30 for the Left and 31 for the Right. (Thus, the Intermargin is actually taken as the rightmost column of the Left Bank.) If NC(33) is 6 or greater, all margins must be entered in the appropriate card columns or a Matt Limits Exceeded error is indicated, since none of the margins are permitted to be zero. (Note, however, that if NC(33) is greater than 6, a blank entry may be read as 100.) Normally, the Left Bank is generated from the right to the left and the Right Bank from the left to the right, but the direction of generation of either or both Banks may be reversed by the N CTRL card.

If NC(32) does not contain a Boolean 1 (a decimal 1,3,5, or 7 on N CTRL card column 32), then the contents of N CTRL card columns 48-51 are ignored and the First Matt Print Line is set to 1 and the Last MATT Print Line is set to JL (line 50 if the system tape is being used, or the value of JLL if an off-system tape is being used). If NC(32) does contain a Boolean 1, then the First and Last MATT Print Lines are set from the N CTRL card. The First Print Line is checked to see that it is greater than 0 and less then or equal to the Last Print Line, and the Last Print Line is checked to see that it is less than or equal to JL. Both values must appear if NC(32) contains a Boolean 1, or a Matt Limits Exceeded error is signaled.

If the Margins or the First and Last Print Lines have been externally set, or if SUBROUTINE SYMTRY is called, or if any of the PROBABILITY TABLE DATA CHECKS has been suppressed, then the MATT and PRNT matrices are cleared in all locations.

(7) RIGHT BANK START, BLOCK NUMBER 5000, sets several index values and then normally goes to RIGHT BANK CONTROL 2, BLOCK NUMBER 6500, (unless SUBROUTINE SYMTRY is called, in which case the program goes directly to LEFT BANK START). In RIGHT BANK CONTROL 2, the sequencing of distributions for the generation of MATTS is begun. The right half of the LL Vector is searched for the first positive value, beginning with LL(26). (Thus the

Probability Data are taken out of IBNK in reverse order from that in which they were fed in.) If an RB N CTRL Takeover is indicated, the corresponding NC value is also checked to see that it is not equal to seven; if it is, the corresponding entry is ignored and the search continues for the next positive LL Vector entry. If no permissable LL Vector entry is found for an LL Vector location greater than 13 an Error Routine is initiated.

If such a value is found, the indexes for the Black Run Probability Distribution (NX) and for the White Run Probability Distribution (NY) are both set equal to the value of that LL entry, which is for the highest distribution for the corresponding entry in IBNK (and which represents the rightmost distribution on the P DATA card entered in IBNK at that point). If, however, an RB Black Run N CTRL Takeover is indicated, NX is set to the corresponding NC value (unless that value is zero, in which case NX is set to the LL Vector value). Similarly, if an RB White Run N CTRL Takeover is indicated, NY is set to the corresponding NC value (unless that value is zero).

All of the indexes used in the actual MATT Generation are now set to the corresponding Right Bank indexes (i.e., LX to NX, LY to NY, and MEA to MED). For the normal positive image, NEG1 is set to MOP and NEG2 is set to 0; however, if a reversed (or 'negative') image is indicated by the N CTRL card, the values of these variables are reversed. In the reversed condition, index NX controls the Right Bank White Run Lengths and NY controls the Right Bank Black Run Lengths. Then, if the Headings and MATTS are not both suppressed, and if no error has occurred, a full page skip is executed and the page count (MCX) is advanced by one.

(8) The MATT GENERATION, BLOCK NUMBER 7000, produces a control matrix which tells the Printout in which coordinates to put an overstrike character (and how many to put there) and in which coordinates to put a blank. It is here that the actual MATT pattern is generated. (This method requires considerably less storage than actually storing all of the overstrike characters, but is considerably faster than generating the pattern line by line for

reasons that should become obvious.) If an error has occurred or if the N CTRL card so indicates, the MATT Generation is bypassed. Depending upon the N CTRL card, the MATT is generated either from the left to the right or from the right to the left (the normal generation is from the Intermargin to the outer margins). A random number (IRA) is generated to decide whether the line (LIN) should start with a Black Run or a White Run. After the first run, the Black and White Runs alternate. The run lengths are determined by the random numbers generated and by the probability numbers entered in IBNK for the particular Mean and distribution indexed. The last run is normally truncated at a margin. It should be noted that if the distribution cumulates to a number less than 4, all random numbers exceeding the high number of the distribution will be rejected. Consequently, probabilities in increments of 1/3, 1/2, or 1 are possible (although obviously the two latter sets would be subsets of the normal one of increments of 1/4). This unit is protected against looping by a check of the last run length position in the IBNK entry to or less than any of the probability numbers. In such an event, if the last position is 0, the line is abruptly terminated at that point. Only one Bank of the total MATT pattern is generated at any one time. If the right Bank has just been generated, the program procedes to LEFT BANK START; if the left bank has just been generated, the program procedes through the MATT PRINTOUT (unless SUBROUTINE SYMTRY is called, in which case the call occurs first, providing no error has occurred.)

After a Right Bank pattern has been generated, all possible Left Bank patterns are generated and each full pattern written on tape before a change in the Right Bank pattern occurs. Within the given constraints, 119 different Left Bank patterns are possible, although it is possible to generate 325 Left Bank patterns from one set of 13 Left Bank P DATA cards.

(9) In LEFT BANK START, BLOCK NUMBER 9000, after the left half of the LL Vector has been searched for the first permissible positive value (assuming that one exists, but if not, an Error Routine is initiated), the program procedes to LEFT BANK CONTROL 2, BLOCK NUMBER 10500, where the Left Bank Black Run Probability

Distribution index (LX) and the Left Bank White Run Probability Distribution index (LY) are both set to the LL Vector value (or either one or both may be set to the NC value, as the N CTRL card directs). Note that the N CTRL can reverse the Left Bank logic to generate 'negative' also, in which case LX controls White Runs and LY controls Black Runs. All of the contants needed for the MATT generation are set in Left Bank Start (since only Left Bank MATTS are generated until all possible Left Bank combinations are exhausted). If SUBROUTINE SYMTRY is called, the variable for the random number printout, SC(71), is set to ORA; otherwise, it remains set to the value of ORA just prior to the preceding Right Bank MATT Generation. The program then retuns to MATT Generation and generates the left bank of the MATT.

(10) The program then procedes to MATT PRINTOUT, BLOCK NUMBER 8000, where the MATT Count is checked. If it equals or exceeds NC(51), the program goes to FINAL OUTPUT, otherwise it writes a complete MATT on the output tape, if no error has occurred (although the Heading and/or the MATT can both be suppressed by the N CTRL card.) Since separate overstrike words are used for the Left Bank and Right Bank, the PRNT Matrix first stores the appropriate word in its left half and then stores the right half before being written out to produce one line of output (1-8 times overstrike, depending upon the setting of MOP). It should be noted that the number of overstruck characters is individually veriable for each MATT coordinate, although this feature is <u>not</u> taken advantage of by the main program. (The number of characters overstruck is equal to the value of the number at the appropriate coordinate of the Control Matrix, or to the value of MOP, whichever is less. The characters are taken out of the FOG Vector beginning with the first character for each word. Thus, if the MATT coordinate value is 3, but MOP is 6, and the FOGVEC word is ABCDEF only the letters A,B, and C are overstruck.) Eventually, this feature will be utilized by one or more Symtry Routines to generate patterns varying only in shades of grey, or in shades of grey and run lengths. Finally, SENSE SWITCH 5 is checked and, if it

is down, a copy of the MATT Heading is printed on-line. If SUBROUTINE SYMTRY is called, the program loops back to repeat the call on SYMTRY. Otherwise, the program goes on to the LEFT BANK CONTROL 1.

(11) In LEFT BANK CONTROL 1, BLOCK NUMBER 9000, index LY is stepped down 1 and, if LY is still greater than 0, the program returns to MATT Generation and generates a new Left Bank with the new LY distribution and the old LX distribution. If SUBROUTINE SYMTRY is called, the variable for the random number printout, SC(71), is set to ORA; otherwise it is reset to zero (since a Job does not begin with a Left Bank generation unless SUBROUTINE SYMTRY is called.) When LY goes to zero, LX is stepped down by 1 and, if it is still positive, LY is reset to its starting value and a new cycle of MATT generation begun. When LX goes to 0, MEA is stepped down until a new permissible LL(MEA) value greater than 0 is found. LX and LY are set to this new value or to NC(MEA) and a new cycle is begun. When MEA goes to 0, the program goes to RIGHT BANK CONTROL 1.

(12) At RIGHT BANK CONTROL 1, BLOCK NUMBER 6000, a check is made to see if it is desired that the Right Bank be stepped. Unless the N CTRL specifically calls for Right Bank changes, the program goes to FINAL OUTPUT at this point. The principal purpose of this feature is to prevent excessive output in case of a user error. If the N CTRL card calls for the Right Bank to step, NY is stepped down 1, all of the MATT generation variables are reset for the Right Bank (in Control 2), a new Right Bank MATT is generated, and control is returned to the LEFT BANK START. The stepping of NY, NX, and MED is analogous to the stepping of LY, LX, and MEA. However, for each time a Right Bank index is stepped down by 1, an entire set of Left Bank patterns is generated. When MED goes to 0, the program goes to the FINAL OUTPUT.

(13) FINAL OUTPUT, BLOCK NUMBER 11000, checks to see if a loop has occurred in the random number generator, if the N CTRL card so directs. If an error has occurred in the Job, the last message of the error output is written; otherwise, the number of pages of output is calculated. If the FINAL OUTPUT is not suppressed by

N CTRL, the first part writes out substantially the same information as the INITIAL OUTPUT (however, some values change under certain conditions). If there are any entries on the N CTRL card, these data are written out. If there have been calls on XIRAN, (the random number generator) the data pertaining to the random number generation are written out (this output cannot be suppressed), and output is written for a new RANDNO card to be punched bearing the final random number generated and a control number. If any N CTRL codes are punched in the N CTRL card, SUBROUTINE NCRPRT is called to list the codes and the program commands generated by them. Then, if an off-system tape has been used, a copy of the FINAL OUTPUT is written on the system tape, and the desired number of Endfile marks are written on the off-system tape. The First and Last MATT numbers are listed on the system tape (if an off-system tape has been used) even if the FINAL OUTPUT has been suppressed by the N CTRL card. Finally, if the N CTRL calls for a Kickout If Error In Job and if an error has occurred, or if it calls for a Kickout If MC Overflow and the number of MATTS generated is equal to the value in NC(51), the Pass is terminated. Otherwise the program returns to the INITIAL RESET, READIN, AND READOUT and reads in the next Job.

Program Description, Subroutines

SUBROUTINE BAKSP begins by checking to see if an off-system tape has been called for. If it has, the off-system tape is backspaced the appropriate number of records, and the output tape numbers are set to those for the system output tapes. An error message prints on-line indicating the number of the Job in which the error has occurred. (If the printed output has already been allocated to the system tape, the backspacing and on-line message are bypassed.) The error report heading is written on the system tape, control is returned to the calling subroutine, where NOEXEC is increased by 1 (NOEXEC is also used to number the error reports), and the diagnostic error message is written.

ERROR SUBROUTINES (identified by names ending with the letter E) cause a message to be written on the system tape identifying the data error initiating the Error Routine. Upon entering any error subroutine, the error flag, NOEXEC, is checked and, if no previous error has occurred, SUBROUTINE BAKSP is called.

SUBROUTINE FINISH checks the off-system tape flag FIN (which is set only if SUBROUTINE TAPOU is called). If the flag is not set, the program skips to the SENSE SWITCH flag check. Otherwise, a message is printed for the operator to disregard all previous instructions, and a list of the tapes to be saved is generated. If a tape is blank because it has never been used or because all of the Jobs assigned to it contain errors, the operator is told not to save it. Three Endfile marks are placed on all punched output tapes which have been used. The approximate number of pages or cards of output is also printed. If the SENSE SWITCHES were all set up at the beginning of the Pass because of the check at that point, a message is printed reminding the operator to reset them. Then, if any off-system tapes are to be saved or if the SENSE SWITCHES are to be reset to their original setting, the program pauses.

SUBROUTINE FOGVE. See ERROR SUBROUTINES.

SUBROUTINE IRAN is an unsophisticated check to see if any looping has occurred within the scope of one Job. (Theoretically, this is extremely unlikely, since the range of the loop is of the order of 10^{10}.) A more sophisticated

check would be to see if the pattern of 'random' numbers generated fit the theoretical model (i.e. if no peculiar runs are generated at a greater than chance expectation.

SUBROUTINE INPUTE. See ERROR SUBROUTINES.

SUBROUTINE IRANE. See ERROR SUBROUTINES.

SUBROUTINE LIMITS. See Main Program Description, Block Number 0000.

SUBROUTINE MTSTAE. See ERROR SUBROUTINES.

SUBROUTINE NCERE. See ERROR SUBROUTINES.

SUBROUTINE NCRPRT. See Main Program Description, Block Number 11000.

SUBROUTINE PDATAE. See ERROR SUBROUTINES.

SUBROUTINE SYM. The SYM SUBROUTINES are described at the end of this section.

SUBROUTINE SYME. See ERROR SUBROUTINES.

SUBROUTINE SYMTRY was added to greatly expand the capacity of the program. Essentially, the purpose of the different Symtry Routines is to generate a Right Bank pattern which is a function of the generated Left Bank pattern. Only two routines are available at this time, but the system is capable of handling 56 different routines, up to 42 of which may be called on any one Job. SUBROUTINE SYMTRY does not itself generate any patterns, but interprets the call commands present in N CTRL card columns 14-26 in order to call in the appropriate SYM SUBROUTINE for the actual pattern generation. On the very first pass through SYMTRY all SYM SUBROUTINES designated by the N CTRL card are called in and go through their error checks only. If at the end of the first pass, the error flag, NOEXEC, is not set, the Subroutine returns to its initial point and goes to the first SYM SUBROUTINE called.

After each SYM SUBROUTINE is executed, SYMTRY returns to the main program for a complete write out of the Left and Right Banks. At the end of MATT PRINTOUT, the program returns to SUBROUTINE SYMTRY and the next SYM SUBROUTINE

is called. Thus, every SYMTRY routine called for is executed before the Left Bank pattern is permitted to change. After a new Left Bank pattern is generated, all of the SYMTRY routines are regenerated with the new pattern. Thus, if 3 Left Bank patterns are generated and 30 SYMTRY routines are called for, 90 complete patterns are written out. Note that, in general, Right Bank N CTRL entries such as Reverse Black and White Runs, Generate Right Bank from Right To Left, and Margins have the appropriate effect upon the SYMTRY patterns generated. (It must be remembered, however, that all commands operate upon the pattern generated from the existing Left Bank pattern. Thus, if both the Left and Right Bank Black and White Runs are reversed, the SYMTRY Right Bank pattern will be a 'negative' of the 'negative' Left Bank pattern.) If SUBROUTINE SYMTRY is called and N CTRL card columns 14 through 26 are blank, only Left Bank patterns are generated and written.

SUBROUTINE TAPNO is called if any off-system tape is requested (by a numeric punch other than 0 in card column 35 or 36) for the print output or the punch output (or both). This subroutine assigns the appropriate logical tape numbers corresponding to the punched numbers in these card fields (according to established local conventions). If an illegal number is punched, the logical tape number remains set to that of the system output tape. JNC is set to 2 if the punch number corresponds to a system input tape, or to 3 if the punch number corresponds to a system output tape.

SUBROUTINE TAPOU is called if any legal off-system tapes are called for by the N CTRL card. This subroutine generates the appropriate on-line instructions for the operator if the tapes have not been used previously on this Pass, causes a program pause to permit him to mount the tapes, and rewinds the tapes. If the tapes have been previously used, a simple on-line message is printed indicating the number of the Job assigned to the tape, and the program does not pause. (Vector NTAP logs printed output and KTAP logs punched output.)

SUBROUTINE XIRAN is a fairly conventional random number generator. However, all positions of the random number generated is chopped with the exeception of two bits to the left of the binary point in order to produce a random number in Fixed Point form varying from 0 to 3.

SUBROUTINE SYM 1 generates Symtry Routine 1 if JAK equals 1 or Symtry Routine 2 if JAK equals 2. If the N CTRL card so directs, the Right Bank control matrix is generated from right to left by this subroutine (which causes an exact image of the Left Bank control matrix to be produced); otherwise, it is generated from left to right (which causes a mirror image to be produced). However, after each complete Right Bank image is generated, a new Left Bank image is generated to its right, then another Right Bank image, and so on, until the Right Margin is reached. If the Right Margin is at position 120 and the Left Margin is to the right of position 1, then the generated matrices continue 'around' columns 120 and 1 to the Left Margin; otherwise the pattern is truncated at the Right Margin. The N CTRL card can cause the generated Right Bank image to be a 'negative' of the Left Bank image. For Symtry Routine 1 (JAK= 1), the Right Bank lines correspond to the Left Bank lines (i.e., the first line of the Left Bank is used to generate the first line of the Right Bank image). For Symtry Routine 2 (JAK = 2), the Right Bank image is inverted with respect to the Left Bank (i.e., the first line of the Left Bank is used to generate the last line of the Right Bank image, and so on).

In general, the control matrix is produced continuously from left to right (except that position 1 is treated as being at the right of position 120). The alternation of Left and Right Bank images is produced by alternating the direction of reading the Left Bank control matrix (and/or the number stored). However, the inversion is produced by storing the image of each Left Bank line in the complementary Right Bank position. (Note that if the direction of generation of the Right Bank is reversed, all Right Bank images will be exact duplicates of the Left Bank for Symtry Routine 1 and simple inversions for Symtry Routine 2, except that if the N CTRL card so directs, these images will appear as 'negatives'.)